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ABSTRACT

Technological literacy is the primary goal of technology education. The systems approach promotes the understanding of technology education. Technology education comprises a study of four technical human-adaptive systems: communications, construction, manufacturing, and transportation. Six classes of inputs are required for technology systems: human resources, knowledge, materials, energy, fixed capital, and money. The communications system represents the ways that humans use system inputs to transfer ideas or information outputs. Visual, acoustical, telecommunication, and computer processes can be used to communicate ideas and information in this system. The construction system represents the ways that humans use system inputs to build structures on sites. Structural design and analysis, structural engineering, personnel relations, financial affairs, structural production, and marketing processes are used by humans to build structures of the system. The manufacturing system represents the ways that humans use system inputs to produce goods in a factory. Ownership and organization, research and development, industrial relations, financial affairs, production, and marketing are common process areas. The transportation system represents the ways in which humans transport people and goods from one location to another. These ways include propulsion, suspension, guidance, control, structure, and support. (33 references) (NLA)

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Technology Education

A PRIMER

Leonard A. Colelli

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Table of Contents

Introduction 1

The Evolution of Technology Education 2

The Universal Systems Model 7

Technology Systems 8

Technology System Inputs 9

- Human Resources 9
- Knowledge 9
- Materials 9
- Energy 10
- Fixed Capital 10
- Money 11

The Communication System 13

- Visual Communications 13
- Acoustical Communications 15
- Telecommunications 16
- Computer Communications 17

The Construction System 20

- Structural Design and Analysis 20
- Structural Engineering 22
- Personnel Relations 23
- Financial Affairs 24
- Structural Production 26
- Marketing 26

The Manufacturing System 28

- Ownership in Manufacturing 28
- Organization in Manufacturing 30
- Research and Development 32
- Industrial Relations 33
- Financial Affairs 35
- Production 36
- Marketing 39

The Transportation System 41

- Environments 42
- Propulsion 42
- Suspension 44
- Guidance 45
- Control 45
- Structure 46
- Support 46

Technology Education System Outputs 48

Summary 49

Bibliography 51

Introduction

What is technology education? Inquiring minds want to know! This monograph is designed to introduce inservice teachers, teacher educators, graduate students, preservice teachers in curriculum or methods classes, administrators, supervisors and legislators to the content and structure of a body of knowledge called technology education. The concepts and activities that will be examined below have generated considerable excitement among all who are concerned about preparing individuals to become literate (able to function effectively) in a technological world. This new form of literacy, called "technological literacy," is the primary goal of technology education.

The pages that follow provide a synthesis of literature that describes selected content and activity areas of technology education. The major content organizers in this manuscript (system inputs, communication processes, construction processes, manufacturing processes, transportation processes, and system outputs) are based on the Jackson's Mill Curriculum Theory (Hales and Snyder, 1981). However, the specific organization of content within each of these six content areas is a synthesis of the Jackson's Mill Curriculum Theory, a wide variety of recently published technology education textbooks, technology education state curriculum guides, historical curriculum models and subject matter contributing to the evolution of technology education, and the actual classroom experiences of this author and his colleagues at Fairmont State College.

The discussion will initially focus on the evolution of technology education and a description of a universal systems model. The systems model is used to provide the structural framework for codifying the body of knowledge called technology education. The universal systems model will then be applied to introduce four systems of technology that are used by humans to adapt to their environment.

A detailed analysis of technology education systems will follow. Included in this analysis will be a discussion of six inputs considered generic to all four technology education systems. Separate descriptions of each of the four technology system process areas will follow. A final discussion of technology system outputs will be addressed at the end of the monograph.

The Evolution of Technology Education

The evolution of technology education has a direct historic lineage with manual training, manual arts, industrial arts, and industrial technology education as shown below in Figure 1. Each of these major curricular developments listed above were designed to provide a general populace with broad understandings about the nature of the industrial and/or technological world in which they lived. The primary goal of these curricula has always been to promote literacy rather than vocational efficiency.

Historically, the methods used to generate content and activities for general education curricula dealing with industry and technology have included an analysis of:

- The "Psychology of Occupations" (Dewey),
- Industry and society (Russell and Bonser with their Industrial-Social Theory),
- Major industries (Warner's Laboratory School of Industries),
- Technology (Warner—Curriculum to Reflect Technology),
- Human needs (Maley—Maryland Plan)
- American industry (Face and Flug—American Industry Project)
- Society and the economy (Towers, Lux, and Ray—Industrial Arts Curriculum Project)
- Society and culture (Paul DeVore),
- Industrial systems (Yoho—Orchestrated Systems Approach), and most recently
- Technical human-adaptive systems (Jackson's Mill Curriculum Theory).

Vocational education curriculum developers have always used a trade and job analysis technique to generate content and activities for their students. This analysis approach, brought to America by the Russians during the 1800's, is designed to focus attention on selected occupations (such as cabinetmakers, carpenters, welders, or drafters). The primary goal of vocational education has always been to promote a high degree of technical skill development in a relatively narrow job cluster (vocational efficiency). Many conventional industrial arts teachers borrow the trade and job analysis approach from vocational educators as they prepare content and activities for their woodworking, metalworking, printing, and/or drafting courses.

John Dewey's "Psychology of Occupations" identified industry (rather than selected trade skills) as a unique social institution that should be studied from a liberal arts perspective by all individuals. Broad intellectual as well as manual experiences in certain social occupations such as woodworking, metalworking, weaving, sewing, and cooking were recommended for study because these experiences were an integral part of daily life for all individuals at that time. Perhaps even more important was the fact that these experiences satisfied basic constructive, investigative, experimental, and social needs of humans. (Dewey, 1900)

James Russell and Gordon Bonser developed the Russell-Bonser Plan or Industrial-Social Theory to identify content and activities for teaching industrial arts. Both men recognized the importance that industry played in providing products which satisfied basic human needs such as food, clothing, and shelter. Therefore, their plan recommended that a study of vital industries which provide for basic human needs should begin as early as the elementary years. (McPherson, 1976)

William E. Warner first focused on types of industry as a source of developing content and activities for industrial arts at the secondary level during the early 1930's. His Laboratory of Industries was basically a general shop facility composed of many smaller areas designed to provide learning experiences from major industries organized by material (wood, metal, ceramic), by process (printing), and by abstract concept (electricity). (Towers et al., 1966)

Warner and his associates at The Ohio State University later shifted their focus from industry to analyzing technology as a base for organizing content and learning activities for industrial arts education. Their proposed *Curriculum To Reflect Technology*, in April of 1947, was designed to address the great transformation that was rapidly accelerating our society from an industrial to a technological nature. The major content organizers that were proposed by Warner and his associates were manufacturing, construction, communication, transportation, power, and management. (Warner, 1965)

During the 1950's and 60's many major curriculum development efforts were made to improve the nature of industrial arts and add validity to its inclusion in the general education curriculum in the public schools. (Cochran, 1968) Perhaps the three most influential curriculum developmental efforts of this time period were The Maryland Plan, the American Industry Project, and the Industrial Arts Curriculum Project.

Donald Maley used a "Human Needs Analysis" to identify appropriate methods of teaching industrial arts that would help junior high school and high school students in their natural quest to achieve developmental tasks. The Maryland Plan centered around the organization, occupations, processes, and materials of past technology (anthropological units dealing with tools and machines, power and energy, or communications and transportation), present industry (group project, line production, research and experimentation, and technical developments), and future activities designed to solve major problems facing humankind. (Maley, 1973a, 1973b)

Face, Flug, and Swanson used an analysis of American industry to identify content organizers during the American Industry Project. They defined industry as ". . . a complex of organizations that utilizes the basic resources of men, materials, machines, and money to produce goods and provide services to meet the needs of man" (Face et al., 1965, p. 64). The fourteen major content organizers that were identified by this analysis technique were communication, energy, processes, materials, production, management, marketing, personnel/public/industrial relations, purchasing, research and development, physical facilities, financing, public interest, and transportation. (Face et al., 1965)

Towers, Lux, and Ray analyzed society and the economy (social-economic analysis) to identify and develop a codified body of knowledge for the study of industrial technology education during the industrial arts curriculum project (IACP). The body of knowledge was organized into management, production, and personnel concepts within two broad areas of industry: construction and manufacturing. (Towers et al., 1966)

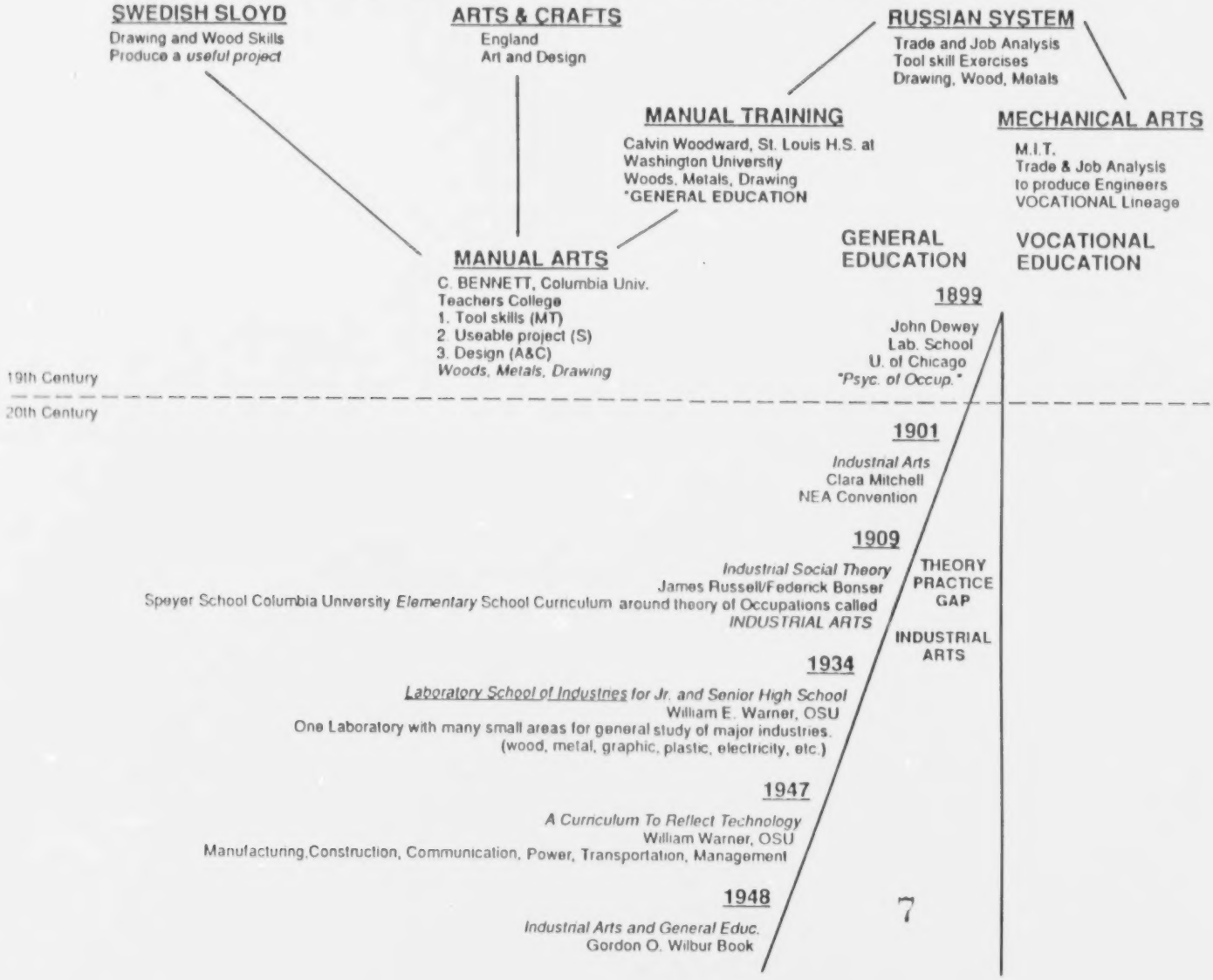
Two one-year junior high school courses—"The World of Construction" and "The World of Manufacturing" were developed, field tested, evaluated, and revised during the six year effort of the industrial arts curriculum project. Each course was developed as a total instructional package comprising textbooks, workbooks, laboratory manuals, teacher guides, achievement tests, and related hardware and audiovisual materials. Two later curriculum efforts: Construction Education Curriculum Project (Blankenbaker et al., 1974) and Manufacturing Education Curriculum Project (Umstattd et al., 1975) were designed to provide for an upward extension of industrial technology to the senior high school level.

Paul DeVore brought further expansion to our content base by employing a social-cultural analysis technique to identify content organizers for the study of technology education. He and his colleagues identified three fundamental types of activity that humans have engaged in throughout recorded history. Humans have been known as producers, communicators, and transporters; therefore, the study of technology would include relevant content and activity experiences in production, communication, and transportation technology. (DeVore, 1980)

Our content base expanded considerably over the past century; however, data first gathered by a Schmitt and Pelley study (Schmitt and Pelley, 1966) and later by the Phase I data gathering portion of the national Standards of Industrial Arts Programs Project (Dugger, 1980) indicated that a serious theory-practice gap exists between inservice industrial arts teachers and contemporary technology education curriculum theory. The focus of secondary level industrial arts programs continued to rely primarily on individual projects constructed with basic hand and machine tool processes of the late 18th and 19th century craftsperson. The data from both studies provided evidence that the three most commonly taught classes continued to be woodworking, metalworking, and drafting. An analysis of Figure 1 shows that these types of content organizers existed in Swedish Sloyd, the Russian System, Manual Training, and Manual Arts education of the eighteenth and early nineteenth centuries.

With this evidence in hand, many leaders in our profession began to feel that perhaps the great

THE EVOLUTION OF TECHNOLOGY EDUCATION



1958

Technology and Industrial Arts
Manufacturing, Construction, Power, Transportation, Electricity, Research, Services

1950's & 60's

Many Major Curriculum Efforts to improve industrial arts in public schools

HUMAN NEEDS ANALYSIS

Maryland Plan
University of Maryland--Human Needs Analysis
Organization, occupations, processes, materials of past, present, and future industry and technology

ANALYSIS OF AM. INDUSTRY

American Industry Project
U. of Wisconsin-Stout
(American Enterprise Approach-13 concepts)
Marketing, finance, transportation, communication, energy, processes, materials, production, management relationships, procurement, property

SOCIAL/ECONOMIC ANALYSIS

Industrial Arts Curriculum Project
IACP - Ohio State U.
2.5 million from U.S. Office of Education
Complete systems of instruction (Textbooks, Lab Manuals, and 185 lesson plans for *INDUSTRIAL TECHNOLOGY.*)
Manufacturing and Construc tion (Junior Highschool)

Early 1970's

INDUSTRIAL TECHNOLOGY

TECHNOLOGY EDUCATION

Technology Education
Paul DeVore, WVU
Communication, Transportation Production

SOCIAL/CULTURAL ANALYSIS

1980

Jackson's Mill Curriculum Theory
Fairmont State

ANALYSIS OF HUMAN-ADAPTIVE SYSTEM

"Bridging the gap between theory and practice"
Manufactunng, Construction, Communications, Transportation

1962-63

Study of Public School
Schmitt/Pelley
Woods, Metals, Drafting

1979

Nationwide Standards Study
VPI
Woods, Metals, Drafting
Prevail in Public School

diversity of content and method provided by the many analysis approaches during the past century have actually contributed to the expansion of the theory-practice gap by creating an overload of too many alternatives. Many leaders felt that it was time to search for a consensus regarding a curricular framework that would include the best attributes of each contemporary approach. (Ray, 1980) A consensus curriculum developed by the major curriculum leaders in our field could provide a common framework that would encourage greater acceptance and reverse the theory-practice gap. This consensus took place at a curriculum symposium held at Jackson's Mill, West Virginia.

The Jackson's Mill Industrial Arts Curriculum Symposium involved 21 industrial arts educators and curriculum leaders who met a number of times from 1979 to 1981 to debate the direction and future of industrial arts. They developed the *Jackson's Mill Industrial Arts Curriculum Theory* from an analysis of technical human-adaptive systems. Technology education content was organized in four areas of "human endeavor": communication, construction, manufacturing, and transportation. (Hales and Snyder, 1981)

The primary goal of this paper is to provide the reader with a holistic perspective of a content base that can be used to design curricula to teach technology education. The content discussed herein was generated from an analysis of technological human-adaptive systems. Some of this information will be familiar to readers because, as previously stated, technology education has evolved from the same historical lineage as manual training, manual arts, industrial arts, and industrial technology education. Those familiar with these subjects should therefore be encouraged to view technology education as simply a further broadening of the same curricular base that they have already experienced. However, many new or less familiar concepts and activities will be encountered in the pages that follow.

The key to understanding and effectively teaching technology education lies in one's ability to embrace a holistic perspective of this subject matter. The systems approach for organizing content and activities described below is an extremely effective tool for achieving this goal.

The Universal Systems Model

A system suggests a combination of elements or parts that work together to accomplish a desired goal. A universal model of a system is presented in Figure 2 (Hales and Snyder, 1981, p. 10).

The "inputs" to the system provide all needed resources to accomplish the goals of the system. The "processes" are the action which brings about system goals using the inputs (resources). The "outputs" of the system include the ends or goals (products, services, societal impacts). "Feedback" adds an element of control to system operations. Evaluation can be conducted at any position in the system to see if things are going as planned. Corrections can be made in inputs or processes if needed to achieve acceptable outputs from the system. (Hales and Snyder, 1981, p. 11)

The systems model is a tool which can be used to provide a framework for analyzing problems or organizing and structuring phenomena in many disciplines. "Nearly all fields of study from sociology (organization of people) to engineering (organization of hardware processes) use a system approach in order to analyze problems" (Minton and Minton, 1987, p. 116). Applying a systems approach to analyze and codify technology for the purpose of educating our students is simply an extension of this logic.

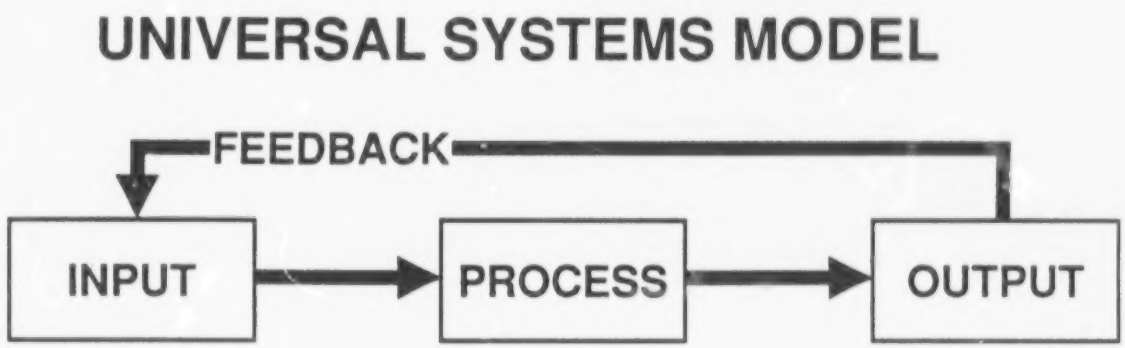


Figure 2: The Universal Systems Model

Technology Systems

Technology is considered a body of knowledge of the technical ways that humans adapt (change) their environment to satisfy their needs. Throughout recorded history, humans have been described as communicators, transporters, and producers of structures and products. Humans have engaged in these forms of activities to satisfy their "basic needs of food, clothing, shelter—as well as providing other goods, services, and means for extending human potential" (Hales and Snyder, 1981, p. 6). Therefore, it is not surprising that the most widely accepted definition of technology education comprises a study of four technical human-adaptive systems: Communications, Construction, Manufacturing, and Transportation. These are the major content and activity areas for technology education.

The technology education curriculum is designed to provide a balanced mix of theoretical and practical information with an abundant amount of hands-on activities included to reinforce conceptual understanding. The intent is to take advantage of students' interest in discovering, creating, problem solving, and constructing, with a variety of tools, machines, materials, and processes within each of the four systems of technology.

Technology education has the same activity-based heritage as manual training, manual arts, industrial arts, and industrial technology education. However, the content base (body of knowledge) and hands-on activities are designed to provide much more than selected engineering and production processes of the cabinetmaker, metal worker, drafter, or printer. Technology education is designed to promote *technological literacy* for a general populace who have lost touch (are not literate) with the technological aspects of our society.

The long term goal of technology education is to promote technological literacy as a basic focal point in the general education of all individuals. This type of education will provide students with basic understandings and skills (literacy) needed to function effectively in a technological world.

Technology System Inputs

Six general classes of inputs are required for technology systems: people, knowledge, materials, energy, fixed capital, and money. These inputs are considered generic for any of the four systems. Content and hands-on learning activities designed to teach concepts relating to these inputs are considered equally as relevant to the study of technology as a conceptual understanding of system process areas.

Human Resources

Human beings (people) can be thought of as the most important input to the system. (Hales and Snyder, 1981, p. 11)

> Without people, and their needs and wants, a human adaptive system would not exist. People bring to the system a varied background of knowledge, attitudes, and skills that are needed to make the system work.

People perform the work in the process areas of each of the four technology education systems. The work can be "physical (worker on an assembly line)," "mental (work of a researcher)," or a "mixture of both physical and mental work" (Lux and Ray, 1971, p. 36).

Knowledge

Knowledge is fundamental to the successful accomplishment of system goals. Knowledge "exists within people or is retrieved or generated by people" (Hales and Snyder, 1981, p. 11).

People bring to the system the knowledge of the sciences (descriptive knowledge), knowledge of humanities (prescriptive knowledge), and knowledge of mathematics/syntax/logic (formal knowledge). Knowledge of technology (praxiological knowledge) is generated by each of the technology systems. (Lux and Ray, 1969; Hales and Snyder, 1981, p. 12) The three specific types of technological knowledge that each of the four systems depend on for efficient daily operation are: how to manage the system (management knowledge), how to interact with people (personnel knowledge), and how to perform technical process area activities (process knowledge).

Materials

Materials can be obtained from the earth, sea, and air. They can be used in their natural state or can be refined/processed into more usable standard forms.

Materials that biologically replace themselves in a relatively short time span are called reproducible materials. Examples of reproducible materials are plants (cotton, vegetables, fruit) and animals (cattle, sheep, poultry).

Materials that cannot replace themselves (are finite in nature) are called nonreproducible mineral materials. According to Lux and Ray (1971), there are three main kinds of mineral resources: 1) mineral fuels, 2) nonmetallic minerals, and 3) metallic minerals.

- **Mineral fuels** include coal, lignite, peat, petroleum and natural gas. These fuels are now nonliving raw materials, but they came from living things. Partly decayed plants and animals were trapped in sediments (layers of fine matter) in the oceans and on land. . . . All these materials developed through physical and chemical changes in the trapped plants and animals.
- **Nonmetallic minerals** include construction materials like sand, gravel, and building stone. There are also abrasive (grinding) materials like corundum, and insulating (protecting) materials like asbestos. Other

nonmetallic minerals (gypsum, clay, lime, and sulphur) have many uses in industry.

- **Metallic minerals** are the ores of all the metals. Iron, copper, aluminum, and the other metals are gotten from these raw materials. These metals are widely used in manufacturing. (pp. 238–239)

Materials are also classified into three groups based on atomic, mechanical, electrical, optical, and other characteristics. These material classifications are called metallic (metals), ceramic, and polymeric (plastics and woods).

Metallic Materials

Metallic materials have an orderly arrangement of atoms in their microstructures that solidify into distinct geometric patterns (cubes, hexagons, etc.). They form metallically bonded crystals which conduct heat and electricity very well, can be bent and stretched to a great extent without breaking, and are lustrous in appearance.

Ceramic Materials

Ceramic materials include all the examples listed in the nonmetallic mineral group above. In some instances, these materials are synthetic combinations of both nonmetallic and metallic materials (aluminum oxide, silicon carbide, etc.). Ceramic materials (with exception of glass) also have an orderly arrangement of atoms in their microstructures. Their atoms are covalently and ionically bonded into layers of crystal chains. These materials tend to be strong, hard, and brittle. They are also poor conductors of heat and electricity (good electrical and thermal insulators).

Polymer Materials

Polymers (plants [woods], animals, and plastics) originate from the mineral fuel and reproducible plant and animal material classifications above. Their atoms are covalently bonded into units called MERS. These units can be combined into long POLYmer (multiple MER) molecular chain shapes which are layered and can be interlocked together. Plastic materials are formed this way synthetically (through a process called polymerization); this microstructure occurs naturally in plants and animals. Polymers are poor conductors of heat and electricity.

Energy

Energy represents the ability to perform work. Much of the activity that takes place within technology systems requires energy beyond what humans are capable of providing on their own. This energy is harnessed from nature to fuel the process activity areas within each technology system.

There are six generally accepted classes of energy: 1) mechanical, 2) radiant, 3) chemical, 4) heat, 5) electrical, 6) nuclear.

According to Lux and Ray (1971, p. 244):

> A rotating turbine, a moving piston, and a coiled spring might be examples of mechanical energy. Radiant energy includes light, radio waves, and X rays. Chemical energy is stored in the atomic and molecular bonds of food and fuels. Heat energy is used for warmth and for changing water to steam. Electrical energy can be found in electric currents and magnets. Nuclear energy is the most powerful form man can use. It comes from the forces holding together the nucleus (center or core) of an atom.

Energy is not destroyed when it is used; it simply changes from one form to another. For example, when an incandescent light bulb is turned on, electrical energy is converted into radiant and heat energy.

Energy is harnessed when humans "collect, contain, and control it" (Lux and Ray, 1971, p. 245). Windmills, sails, and gliders are some examples of how moving air can be harnessed. Turbines can be used to harness energy from moving water in rivers, ocean tides, and geothermal upheavals. The chemical energy in natural fuels such as coal, oil, gas, and wood can be harnessed in several ways. "They are 1) drilling for oil and gas, mining coal and cutting wood; 2) refining (oil) into usable fuels; 3) moving and storing the fuel; and 4) controlling the burning of the fuel" (Lux and Ray, 1971, p. 247). Radiant energy from the sun can be harnessed by solar cells, solar ovens, or passive systems. Finally, nuclear energy can be harnessed in a nuclear reactor by a process called fission.

Fixed Capital

Fixed capital refers to tools, machines, buildings, and land. This input is called "fixed" because

the investment money that was used to purchase these items is locked in for a relatively long period of time (if not permanently).

Tools are devices that help people extend their human potential for accomplishing work. "With tools, work can be done faster, better, and more safely" (Fales et al., 1986, p. 38). Many kinds of tools are use by humans as they work within the four systems of technology education. According to Fales et al. (1986, p. 39), tools can be classified as:

- Hand tools—screwdrivers, knives, pliers
- Portable power tools—drills, personal computers
- Power machines and equipment—bandsaws, lathes
- Industrial machines and equipment

Fales et al. further indicate that some tools are simple and some are complex (having many parts).

All tools are related to one or more of six basic machine structures: the wheel, the lever, the inclined plane, the pulley, the screw, and the wedge. (Fales et al., 1986, pp. 39–40):

> The blade of a circular saw uses sharp teeth (wedges) around the edge of a wheel to cut wood. A pair of pliers is a form of lever. It increases the user's grip on an object. A twist drill is really an inclined plane in spiral form (winding from point to point). The blade in a band saw runs on pulleys. A screw thread allows a C-clamp to be tightened. A block plane uses a wedge to shave thin strips of wood.

It really doesn't matter how large or small the tool is or how the tool is used. One or more of the six basic machine structures will be found in all tools.

Money

The money input is used to pay for all the other system inputs as well as to pay workers and make investments. The money input is sometimes referred to as working capital because funds are not locked into long term permanent items such as land, buildings, and equipment.

These funds are used to buy materials which will be processed and sold by manufacturing and construction firms. Funds are also used to pay the cost of services which communicate messages and transport people and materials. The goal is to regain the initial investment plus a profit in a relatively short time span so the company can remain solvent. Investments can also be made so that money will be out working in the marketplace earning more money for system owners and operators.

Working capital is created when people save money in banks, credit unions, and other saving institutions or invest directly into businesses. Businesses operating in any of the four technology education systems generally acquire working capital (finance) by selling stocks and bonds or through loans from savings institutions and insurance companies.

The Communication System

The communication system represents the ways that humans use system inputs to transfer ideas or information outputs. This system may use human to human, human to machine, machine to human, or machine to machine channels.

Humans have communicated ideas and information since dim antiquity. There was a time when echoing drum beats or smoke signals filled the air and illustrations in cave walls or verbal recitals passed down stories of prior experiences from generation to generation. Communication has been a critical element of every great society, historical as well as contemporary.

Minton and Minton (1987) outline three primary purposes of communication in our modern world (pp. 195–196):

> First, communication conveys past happenings. The record of the past allows the advancement of technology because it adds to our knowledge and frees us from the necessity of having to rediscover scientific principles and procedures. Second, communication relates current events. The technology of television and communication satellites allows us to watch events all over the world and also in space, as they occur. Electronic communication places us in direct contact with major events at the flip of a switch. Third, communication alerts us to possible future occurrences. Early warnings of impending tornadoes, floods, and hurricanes have helped save many lives. Dates for future events can be announced, as can last-minute changes in schedules and alternative programs.

Figure 3 shows the major elements in the communication system. Since the system inputs have been previously addressed, the primary focus of this discussion will be on the communication process area. Visual, acoustical, telecommunication, and computer processes can be used to communicate ideas and information in this system. (Bolyard et al., 1986).

Once inputs are received by the system, messages can be designed, encoded, transmitted, received, stored, retrieved, decoded, and/or corrected within each of these four communication process areas. Concepts concerning feedback (a sign that the message has been received, and interference (a distortion of signals intended for a receiver) can also be addressed (Seymour, 1987, pp. 22–27).

Visual Communications

Visual communicating basically involves messages that are designed to have eye appeal or graphic impact. Included are drawing processes, graphic printing processes, and photographic printing processes (Bolyard et al., 1986, pp. 6–9).

Drawing Processes

Drawing processes may involve students with measurement, sketching, lettering, orthographic, and pictorial projection experiences. Computer assisted drawing (CAD) experiences can modernize the above activities when available.

Measurement can be taught in either customary (English) or System International (SI—metric) units. Lettering may be practiced by hand or by using template and lettering guides, pressure sensitives, a tape machine (Kroy), or other methods. Orthographic projections teach students how to represent the three major dimensions (width, height, depth) of objects with multiple views. Finally, pictorials teach students how to represent the three major dimensions of objects with one view in either an oblique, an axiometric (isometric), or a perspective format.

Graphic Printing

Graphic printing may involve students with image design, image assembly, image conversion,

image carrier (plate) preparation, image transfer (printing), and finishing processes. These are generic processes which can be applied to any of the six major image transfer (printing) processes below (Seymour et al., 1987, pp. 117–121).

- **Relief**—letterpress or flexographic; raised surface printing
- **Planographic**—offset lithography; flat plate surface printing
- **Screen**—stencil; through plate surface printing
- **Gravure**—Intaglio; -below surface printing
- **Electrostatic**—photocopying
- **Specialty**—ditto, mimeograph, diazo, thermo-transfer, ink-jet

Any or all of these methods of printing can be used as a medium for developing a conceptual understanding of the generic design, assembly, conversion, plate-making, image transfer, and finishing processes mentioned above.

Photographic Printing

Photographic printing processes can be classified into two major types: line photography and continuous tone photography. Line photographs contain images (lines and solids shapes) that are equal in density (darkness) or color. There are no shades of gray or variations in color with line photographs. "Continuous tone photographs contain many shades of gray, or variations in color" (Seymour, et al., p. 150).

Examples of line photography might include inked drawings, commercially prepared clip art, and newspaper halftone photographs. Although newspaper photographs appear to have tone and color variation, they are actually composed of hundreds of multi-sized and shaped dots of equal density which trick the human eye into thinking that they are continuous tone. Examples of continuous tone photography include negative or positive prints of scenic country settings, pencil sketches, charcoal renderings, ink washes, or water color paintings.

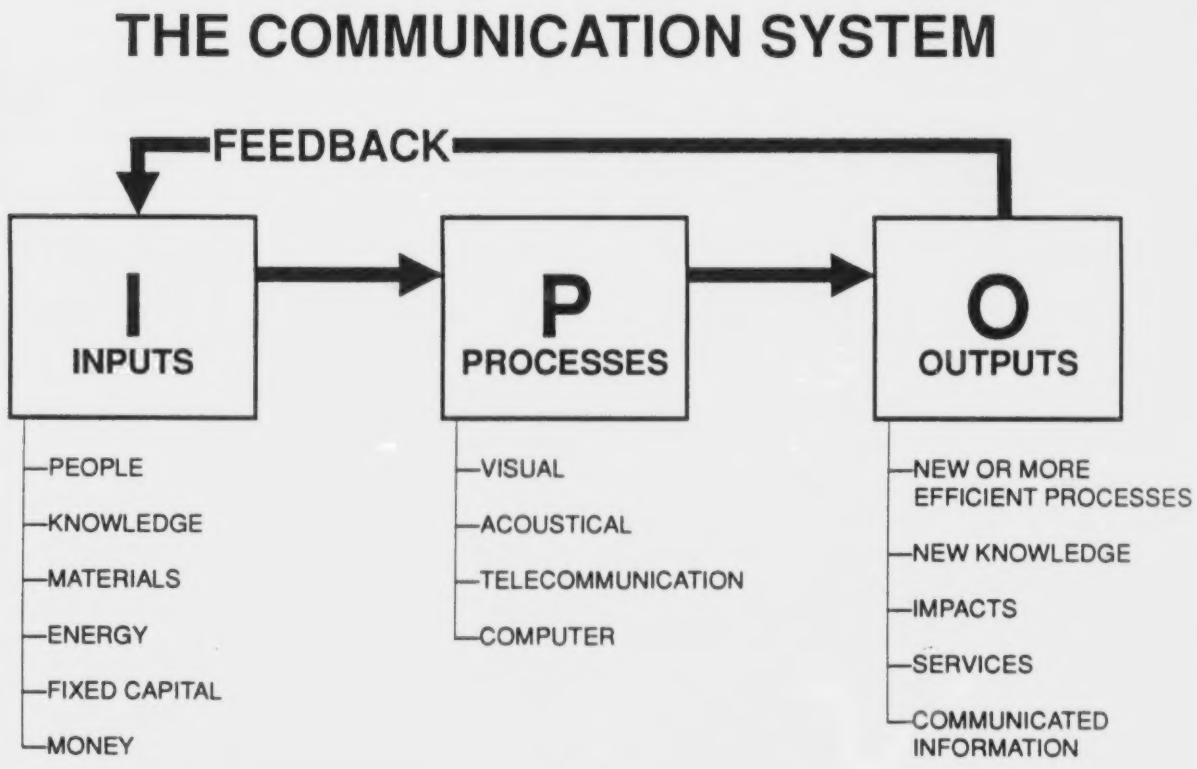


Figure 3: The Communication System

Regardless of whether the photography is line or continuous tone, concepts relating to picture composition, camera handling techniques, film processing (developing, stopping, fixing, washing), film printing, and safety with film processing chemicals should be important curricular considerations. Student constructed pin-hole cameras, instamatic cameras, or small one-time-use disposable cameras can be used to facilitate this conceptual understanding.

Cinematography "the science of motion-picture photography . . . is a very popular and profitable form of communication" (Seymour et al., 1987, p. 47). Activities relating to script and storyboard writing, casting, staging, set-designing, directing, filming, and editing can be simulated in the classroom with easily constructed stage props and a black and white or color video camera. This content and method is also commonly used as an educational experience when studying the marketing process area of the manufacturing system. Students in marketing may produce a television commercial to advertise and sell a product that they may be manufacturing.

Acoustical Communications

Acoustical communication "involves transmitting information with sound, both audible and inaudible, to humans" (Seymour et al., 1987, p. 216). Sound waves are created when there is a disturbance in something that has mass and is also elastic. Seymour et al. (1987, p. 217) explain sound waves in terms of mass and elasticity with the following example.

> Suppose someone standing next to you claps his or her hands. The pressure of two hands coming together (mass) creates a wave in the air surrounding you. The elasticity [flexibility] of the air allows the wave to ripple through the air. The wave then passes through your ear canal and past your eardrum. The eardrum is also elastic. It vibrates from the pressure created by the [clapping] wave. The frequency and pressure of the sound wave is duplicated (copied exactly) by the eardrum.

Acoustical communication may be taught to students through experiences with the nature of sound, acoustical energy transmission, electric communication, sound transducers, and acoustical storage and retrieval processes (Bolyard et al., 1986, p. 10–11).

Nature of Sound and Energy Transmission

Students can learn about the nature of sound through activity experiences designed to teach basic principles such as mass, momentum, elasticity, pitch, loudness, velocity, and the Doppler effect. Acoustical energy transmission can be learned through experiences in musical scaling, musical interval, sound frequency, sound generation, sound amplification (by resonating), sound quality, and how sound waves can be transmitted through air, solids, and liquids (SONAR).

Electric Communication

Electric acoustical communication can be taught by introducing students to simple electric circuits. Concepts dealing with voltage, current flow, resistance, conductors, insulators, electrical storage devices such as the battery, magnetism, and switching are all important curricular considerations. These concepts can be reinforced quite easily by allowing individuals to construct a simple electric circuit sound transmitting and receiving device such as a telegraph. Since the telegraph operates in a current on/current off manner, the principle of pulse modulation can be discussed. Students can apply the principle of pulse modulation if their telegraphs are connected and they are required to transmit and receive Morse Code messages.

Sound Transducers

Transducers are devices that receive one form of energy and retransmit it as another form of energy. A study of sound transducers can lead to an understanding of audio diaphragms (microphones, loudspeakers) and the continuous modulation of sound waves.

A microphone may receive mechanical energy (vibrating sound waves) from a person speaking and retransmit this energy as electrical impulses (vibrating bursts of electrical energy). A loudspeaker may receive amplified vibrating bursts of electrical energy and retransmit this energy as vibrating waves of (mechanical energy) sound that can be heard by human ears.

The above process is called continuous modulation because the current flow in the electrical circuitry is always turned on. The vibrating sound waves that are fed into the microphone cause the electrical current flow to also vibrate. This vibrat-

ing occurs at high and low levels, but is never turned off as in the pulse (on/off) modulated telegraph. These topics can prepare students for further study in electric communication with devices such as the telephone, tape recorders, and phonograph players.

The electric sound communication devices such as the telegraph, telephone, tape recorders/players, and record players differ from electronic telecommunication devices (addressed in a later section of this paper) in that closed path (hard wired) circuits are typically used from sender to receiver. They also use lower technology pulse and continuously modulated sound waves. Electronic telecommunication devices use much more advanced electronic circuitry with band-modulated sound waves that are frequently broadcasted over long distances through the open air (open path). Examples of telecommunication devices might include radios and television.

Acoustical Storage and Retrieval

Students can also learn how acoustical (sound) messages can be stored or retrieved. Audio storage and retrieval of messages or information can be accomplished mechanically (records, punched tapes or drums), magnetically (steel wire, plastic tape, vinyl discs/cards), or with light (laser).

Telecommunications

Telecommunication means sending and receiving messages between distant points via an open path. The open path means that messages are broadcast at selected frequencies (band-modulation) over relatively long distances through open air waves instead of through closed circuits of wire. Permanent wires or cables are not required between stations and receivers. According to Seymour et al. (1987, p. 190):

> [t]here are many types of telecommunication systems [and each] . . . requires a frequency on which to broadcast. Because of the large number of uses involved, some regulation is the responsibility of the Federal Communications Commission (FCC).

The FCC has divided telecommunication into the following four major categories (Seymour et al., 1987, p. 191).

1. **Broadcasting**
   - AM Radio (Amplitude Modulation)
   - FM Radio (Frequency Modulation)
   - Television
   - Links
   - Common Carriers
2. **Citizen Communication**
   - Amateur Citizen Band
3. **Government and Industrial Communication**
   - Armed Services
   - Government Departments
   - Public Safety
   - Industrial Communications
   - Meteorological Services
   - Telemetry
   - Industrial, Scientific, and Medical Equipment
4. **Commercial Transportation Communication**
   - Paging Services and Mobile Car Telephones
   - Mobile Land Vehicles
   - Aeronautical Control
   - Aviation
   - Maritime
   - Navigational Beacons

In most cases, the user must acquire a license to communicate in each specific category above.

Telecommunications can be taught to students through a variety of experiences. Low cost activities can be designed to reinforce a conceptual understanding of radio broadcasting, television broadcasting, radio detection and ranging (RADAR), microwave/masers, communication satellites, lasers and the transmission of fiber optic signals (Bolyard et al., 1986, pp. 11–12).

Radio Communication

Individuals can learn about radio communications by studying early radios, the regulation of radio transmission, types of modulation (Amplitude [AM], frequency [FM], and others), operation of a radio, and program production. A class could actually become involved in the writing and tape recording of a short radio spot (commercial). They could also build a simple crystal radio that operates with germanium diode, wire, and earphones.

Television Communication

Television communication can be addressed through topics relating to mechanical scanning systems, the cathode ray tube (CRT), video and audio transmission, signal storage and retrieval via a video camera/recorder (VCR) and video disk, and

television program production. The same type of activity that was discussed in the visual cinematography unit can again be used to reinforce concepts in this unit. Students can become very actively involved in developing a short television commercial, story, or play.

Microwave/Maser/Satellite/Laser/Fiber Optic

Microwave/maser transmission, communication satellites, lasers, and fiber optic communication can be studied by requiring students to trace their historical development and by examining common every day applications. Students may construct scale models of related hardware to enhance their conceptual understanding.

Modulated lasers (needed for communicating messages via light) designed for educational settings can now be purchased for as little as $400. These can be used (among many other applications) to demonstrate the direct (straight) line transmission of sound by light beam or the more practical nonaligned transmission of sound through fiber optic cables.

Thomas Edison's photophone, a direct precursor of laser and fiber optic communication, can be built to demonstrate sound transmission by light and to reinforce the concept of a transducer. This simple device can be built with a flashlight, a mirror glued to a Quaker Oats box, wire, a small radio frequency amplifier, a small solar cell, and a tape recorder. The light beam from the flashlight is reflected off the mirror and onto the solar cell. When a person speaks into the oat box, the mirror vibrates. This causes the beam of light to be modulated (vibrated) at the same frequency that the person is speaking. The modulated light beam hits the solar cell (transducer) and causes vibrating electrical pulses to be sent into the amplifier. The amplified electrical pulses are connected to a tape recorder by an external jack and are recorded. The message can be played back for the entire class to hear.

Disadvantages of this communication device will quickly be discovered by the students and can be directly linked to improvements that were applied to modern fiber optic communication with lasers.

Computer Communications

A computer is a tool that humans can use to accept, store, alter, and transfer information called data. According to Seymour et al. (1987, p. 140):

> Data is actually information that is not organized. This data is input into a computer. It is processed into usable form. The organized data is then released as output data. This is how data processing got its name.

Analog computers (slide rule) are designed to measure magnitudes in terms of voltage, length, current, or shaft rotations. Digital computers work entirely with numbers and require a language to act as an interpreter so humans can understand the computer and the computer can understand humans.

Computer communications may be addressed by introducing students to the historical development of computers, computer system components and operations, simple computer language and programming techniques, and some computer applications (Bolyard et al., 1986, pp. 12–13).

GENERATION	STARTING DATE	PRINCIPAL COMPONENT	TIMING UNIT
First	1946	vacuum tube	millisecond (thousandth of a sec.)
Second	1958	transistor	microsecond (millionth of a sec.)
Third	1964	large-scale integrated circuits (IC's)	nanosecond (billionth of a sec.)
Fourth	1975	very large-scale integrated circuits (VLSI)	picosecond (trillionth of a sec.)

Historical Development

An historical development of computers might require individuals to conduct research and develop a time line of computer type devices such as the abacus, Charles Babbage's difference engine or his proposed analytical engine, Herman Hollerith's punched card tabulating machine used for the 1890 U.S. population census, and others (Mark I, UNIVAC 1, etc.).

Recently developed computers could also be examined in terms of selected generation characteristics. Jones and Robb (1986, p. 273) illustrate electronic component and timing (speed) characteristics of four generations of modern computers.

Students might also try to predict some characteristics of fifth generation "supercomputers" that are currently under development.

Components and Operations

A unit on computer system components and operations could include experiences with input devices, the central processing unit (CPU), output devices, and how these operate. Input and output devices are sometimes referred to as peripherals because they tend to be externally attached onto the main body of the computer. Examples of input devices include keyboards, card readers, tape readers, mouse, light pen, touch tablet, optical scanners, and others. Examples of output devices include monitors, plotters, and a variety of printers (dot matrix, ink jet, daisy wheel, train, drum, thermo, laser, etc.).

The main body of the computer is called the central processing unit. The CPU is considered the heart of a computer system and is composed of three sections: the arithmetic/logic, the control unit, and the main memory. The arithmetic/logic unit contains the "computational capability of the computer." This section actually performs instructions and allows the computer to "logically branch through elaborate networks of alternative processes." The control unit "controls the input and output as well as the calculating sequence and timing during computer operation." It directs the processing of all instructions. The main memory is "often a magnetic core of semiconductor" material (Hopeman, 1980, p. 203). It is used to store data and instructions internally while the computer is operating. Magnetic core memories typically lose their storage capability if the power to the computer system is turned off.

Computer memory can be classified as either random access (RAM) or read-only (ROM). Random access memory will allow data to be stored only as long as a magnetic core computer is turned on. The reason that it is called random access is that once data is loaded into the computer memory, it can be located and accessed very quickly regardless of its location in the memory. Prior to turning off the computer system, data must be loaded onto permanent data storage devices such as disks, drums, and tapes. Disk operating instructions (DOS) are usually loaded into RAM.

Read-only memory (ROM) is permanently installed at the factory. User programs and data are not stored in this memory; only internal instructions that allow the computer to function properly. Access to this memory is very difficult, ". . . it cannot be erased and is difficult to change" (Seymour et al., 1987, p. 244).

"Starting up a computer is called booting the system" (Jones and Robb, 1986, p. 305). This process is accomplished by turning on the computer and loading a set of operating instructions. The operating instructions (operating system) is the "master" set of programs which control the computer. In a personal microcomputer these instructions are called the disk operating system (DOS).

Language and Programming

A computer language can be explained as a way that humans can talk to a computer so that the computer can understand what we are saying. The language also allows the computer to talk to humans so that we can understand what the computer is saying. Some common computer languages are listed below.

1. BASIC—(Beginner's All-Purpose Symbolic Instructional Code) This is a very popular language and is used for most personal computers.
2. COBOL—(Common Business Oriented Language) Used primarily for developing large business programs.
3. FORTRAN—(FORmula TRANslation) Widely used in mathematical and engineering applications.
4. PL/1 — (Programmer's Language) Also used for science and business programming.
5. Pascal — Rapidly gaining on BASIC as the most popular language for beginning programmers.

Students can easily learn simple programming techniques in the BASIC language. "Instructions in BASIC are easy to understand. It is possible to write simple programs with only a few hours of training" (Jones and Robb; 1986, p. 306). Even

elementary students are quite capable of learning and applying the following BASIC command statements (as well as others) in simple programming exercises designed to teach keyboarding techniques, data storage (SAVE) and retrieval (LOAD), flowcharting, word processing, and mathematical calculating.

- REM—Inserts a REMARK into the program
- PRINT—Displays program data or messages on screen. Can also print blank spaces.
- INPUT—To enter information from keyboard and assign to a variable.
- READ—To search for data within program and assign to a variable.
- DATA—Stores characters or numbers within the program to be accessed by READ statement.
- FOR—Beginning of loop which will be repeated a given number of times.
- NEXT—End of a loop started with FOR statement IF/THEN—Testing decision-making for branching.
- GOTO—Direct movement to a specific line number. Usually in conjunction with IF/THEN.
- END—Ends program execution.

Computer Applications

A final topic in computer communications could be computer applications. Discussions or hands-on activities with word processing, data base, spreadsheet, graphics, publishing/printing, household budgeting and management, or other applications software packages can show how computers can be used as a very valuable tool to aid humans in many of their daily activities.

The Construction System

The construction system represents the ways that humans use system inputs to build structures (outputs) on sites. The key word is that construction activity takes place on a site rather than in a plant location (where manufacturing occurs). The system inputs (resources) are brought to the site to custom produce (in most cases) a one-of-a-kind project.

Humans have been constructing structures since nomadic tribes began to settle into the first permanent societies. Much of what remains of some of the greatest civilizations on earth are examples of their constructed structures. Even contemporary societies are characterized to a great extent by the quality and character of the structures that they build.

Minton and Minton (1987) have provided examples of three basic kinds of structures that can be produced by the construction system (p. 247).

Building Structures	Nonbuilding Structures	Transportation Surfaces
Houses	Bridges	Sidewalks
Apartment Buildings	Tunnels	Roads and Highways
Factories	Dams	Canals and Locks
Office Buildings	Transmission Towers	Runways

The common processes (unifying themes) that are used to produce any of these structures can be designed onto relevant content and activities for studying the construction system.

Figure 4 shows the major elements in the construction system. Since system inputs have been previously addressed, the primary focus of this discussion will be on the construction process area.

Structural design and analysis, structural engineering, personnel relations, financial affairs, structural production and marketing processes are used by humans to build structures in this system.

Structural Design and Analysis

Construction projects may be designed by architects, engineers, or a combination of the two working as a team.

> Architects develop plans for buildings, shopping centers, and community developments. Engineers design bridges, dams, highways, and utility systems. The architects in charge of a shopping center design will be responsible for the master plan. They will depend on engineers to design certain parts of the project. For example, electrical engineers will design the electrical system. Drainage of the site will be designed by civil engineers. Civil engineers will design the framework of the building (Lux et al., 1982, p. 39).

Other types of engineers (such as mechanical, mining, and chemical) can be involved in construction. Mechanical engineers are responsible for designing machines and machine systems such as those used for heating and cooling, transporting people and freight (elevators and escalators), and the production and transmission of power.

Structural Design

Architects and engineers usually follow an orderly step-by-step process when designing structures. The design process includes identifying a problem, sketching preliminary ideas, refining ideas into more detailed drawings, analyzing construction materials to determine strengths and sizes needed, presenting design solutions (renderings, models, etc.) to clients, decisionmaking, and implementation of the design solution. (Lux et al.,

1982, pp. 37–39).

Henak (1985) and Lux et al. (1982) identified five criteria that architects and engineers consider when designing structures.

1. **Function**—Will the project do what it is supposed to do?
2. **Appearance**—Does the project look good and does it blend with the area around it?
3. **Cost**—Will the project be within the budget?
4. **Strength**—Will the project withstand the forces of nature?
5. **Materials**—Which materials will be the best for the purpose?

These factors are common to all structural designs. The primary factor appears to be function. If the structure does not function properly, the design is considered poor and other factors really don't matter.

Structural Analysis

Structural analysis is very important in construction. Different types of structures require different types of materials and support elements to function safely and efficiently.

Structural elements can be classified into two major categories: rigid and non-rigid. Rigid structural elements include beams, columns, arches, solid plates, parallel grids, shells and others (such as space frames, truss frames, and geodesic domes). Non-rigid structural elements include cables and membranes such as air-inflated and air-supported pneumatic structures. (Komacek, 1986, p. 6)

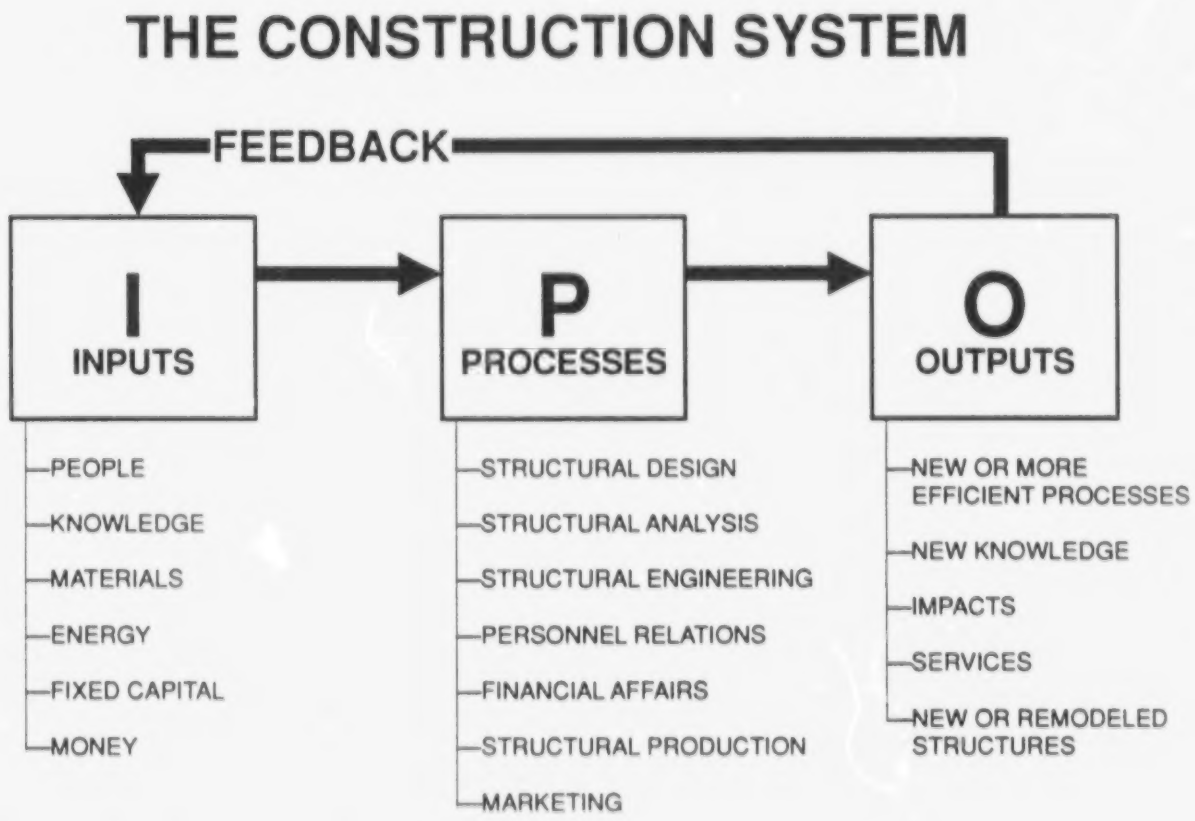


Figure 4: The Construction System

The rigid and non-rigid structural elements above can be used to build the substructures (below ground) or superstructures (above ground) of all constructed projects. Therefore, educational activities related to an analysis of as many of these basic structural elements as possible should be designed into the curricular background of all individuals. Building and testing scale models of these elements can help students understand how structures are supported and why structures stand.

An analysis of structural elements can be expanded into an analysis of types of completed structures. The illustration presented earlier (by Minton and Minton) illustrated examples of building structures (houses, apartment buildings, factories, office buildings), nonbuilding structures (bridges, tunnels, dams, transmission towers), and transportation surfaces (sidewalks, roads/highways, canals/locks, runways). Pipelines and railroads could also be included under transportation surfaces and building structures could include a special unit on energy efficient structures. Examples of energy efficient structures could include active and passive solar, earth sheltered, earth bermed, superinsulated, and air envelope buildings (Komacek, 1986, p. 6).

Building scale models of bridges, geodesic domes, cut-away sections of residential homes, dams, sectional models of highways, pneumatic (air inflatable) structures, and others can prove to be very beneficial to children. The cost of building these models is really quite affordable since materials such as dowel rods, drinking straws, tape, staples, plastic sheeting, plastic tubing, glue, paper styrofoam, balsa wood, marking pens and paints are used. Some models, such as bridges and domes, can be tested for weight/strength ratio efficiency using teacher developed testing apparatuses.

Model building is a construction activity usually performed by architects and professional model makers. Three dimensional structural models as well as two dimensional pictorial renderings are used to present design solutions to clients for their approval. Structural models are also built for testing design solutions and alternatives. Computer modeling is very helpful for simulating static and dynamic forces which may affect structural elements and completed structures. Stress points of structural elements can be better identified, and material fatigue ratios and failure rates can be more accurately predicted through computer simulation.

Structural Engineering

The engineering process simply means working out the details of the design so that a structure can be built. The details are provided in drawings and project specifications.

Drawings

After the refined structural design has been approved, very accurate detailed drawings are made by architects and/or drafters. These drawings, called working drawings, will show exactly where the structure will be placed on the site and how it will be built. The three major types of working drawings are: plans, elevations, and details (Lux et al., 1982, p. 87).

Plan drawings are typically drawn with an observer looking downward from a perspective of a bird (like a top view in orthographic projection). Depending on the size and type of structure, plan drawings could be made of the plot (where structure is located on site), foundation (or basement), floors (horizontal section of each floor—showing walls, windows, doors, etc.), roof, electrical (floor plan with electrical and lighting outlets, switches), climate (heating, cooling, ventilating equipment), and plumbing (all lines and fixtures above and below ground). All structures will not require every one of these plan drawings, however most building structures do.

Elevations are drawn from the perspective of a person standing in front of a structure looking directly at it (like a front view of an orthographic projection). Elevation drawings could be made of the finished front, rear, right side, and left side of the structure (exterior elevations), as well as interior walls.

Finally, detail drawings are made. Detail drawings (sometimes called shop drawings), are used to guide the work of the contractor and construction crew. They show ". . . shape, size, and placement of parts of the project. The part may be a bridge or a bolt" (Henak, 1985, p. 82). Detail drawings can be made of structural parts, electrical parts, mechanical parts, or finish work. (Lux et al., 1982, p. 87).

Project Specifications

Specifications are written instructions to the contractor and construction crew. "They are details about the project that are easier to put into words than into drawings" (Henak, 1985, p. 86). Drawings and specifications tell the contractor the exact materials to use and how to get the job done. Contractors initially refer to project specifications

when preparing their bids to figure out how much it would cost them to build a project.

Lux et al. (1982), have indicated and described four major kinds of specifications: outline, standards, guide, and project (pp. 79–80):

- **Outline specifications** are made at the beginning of a project, when preliminary drawings are being made. These specifications give only the main facts about the materials and how they are to be used.
- **Standards specifications** are made up by companies. In catalogues, companies tell about the use of their own materials. . . . The American Society for Testing and Materials has standards specifications for many materials. In addition, Sweet's Catalog gives specifications for many kinds of work and materials.
- **Guide specifications** provide a model for writing project needs. They are forms and blanks. The blanks can be filled in to show what is needed for a job. They are a guide the writer uses to organize specifications.
- **Project specifications** are the finished specifications for a particular construction project. They are usually made up of outline specifications, standards specifications, and guide specification.

The specifications are usually put into sections and arranged in the order that the project is to be completed. The specifications are placed in a packet called the "project specifications book." Also included in this book are bidding requirements and contract limits (Henak, 1985, p. 89).

Personnel Relations

People are considered the most important input to the construction system. Therefore, personnel processes relating to hiring, education and training, organized labor, safety/working conditions, and advancing on the job are very important to maintaining a happy and productive work force.

Hiring

Construction work differs from manufacturing work in that most construction work is done on a short term basis. "It is common for workers in a [manufacturing] plant to be hired only once or a few times during their work life. It is just as common for construction workers to be hired five to eight times each year" (Henak, 1985, p. 111). Construction personnel are hired in a three step process. They are first recruited, then selected, and finally inducted.

Recruiting can be done by posting signs up at the job site (for walk-in applicants), through advertisements in local papers and trade journals, by placing job orders in an unemployment office, or by calling local union hall agents. The selection process may involve obtaining descriptive background information from applications, determining mental and physical skill levels through testing, and obtaining information about personality, grooming, and a desire to work through face-to-face interviews. Induction involves introducing new employees to the company (what it does and rules, benefits, etc.) and the job itself.

Education and Training

Lux et al. (1982), indicate there are three major groups of construction workers: management workers, production workers, and office workers. Each requires a different kind of education and training.

Management workers "plan, organize, and control production systems." Most construction management people have engineering or architectural backgrounds. Some have attended construction programs or technical institutes. Others have college degrees or courses completed in professional management. Those with engineering backgrounds have had at least:

1. Three or four years of mathematics.
2. Three or four years of English.
3. Two or three years of science.
4. One or two years of industrial arts or technology education. (p. 123)

Production workers can be either skilled or unskilled. Unskilled laborers are usually short-term transient people with little or no background in construction. They are the lowest paid and may only be hired when the industry is booming or in peak seasonal periods such as the summer when many high school and college students are on break and are in need of employment.

Skilled workers participate in a training period called apprenticeship (Lux et al., 1982, p. 125):

> Apprentices receive two kinds of training. They receive between 6000 and 10,000 hours of on-the-job training [usually training along side a skilled worker]. They also get 144 or more hours of classroom instruction per year. Apprentices become skilled workers in about four years.

When apprentices complete all their requirements, they are certified. Skilled certified workers have the greatest opportunities for permanent work and advancement in the construction system.

Office workers perform the day-to-day paperwork that keeps the project running smoothly. Their background usually includes business and/or office training in high schools, trade schools, or college.

Organized Labor

The fundamental purpose of organized labor is to provide workers with one collective voice when negotiating issues with the leaders of a construction firm. Henak (1985) has identified at least 18 different types of unions that do work on construction projects. While some of these are independent unions, many are organized under a larger umbrella organization called the American Federation of Labor-Congress of Industrial Organizations (AFL-CIO). The AFL was originally established to represent the skilled trade-workers and the CIO was established to represent unskilled and semi-skilled industrial workers.

During contract negotiations, the primary goal of management is to limit costs and the primary goal of organized labor is to provide a better life for its union members. The collective bargaining process works to find a balance between the goals of management and the goals of organized labor. Typical bargaining issues include wages, training, working conditions, hours, benefits, promotion, and grievance procedures (Henak, 1985, p. 115).

When contract agreements cannot be reached or grievances are not resolved, pressure can be brought to bear on the company through economic weapons such as worker slowdowns, picketing, boycotting products, and/or strikes. Owners may bring pressure on labor through lockouts, threatened plant closings, and others. (Amrine et al., 1982, pp. 388–389). These pressures can lead to emotion-laden confrontations that have been known to breed violence, physical injury, and property damage. However, organized labor and management generally try to settle unresolved differences peacefully through mediation and arbitration processes.

Advancing

Advancing means that worker assignments are changed. According to Lux et al., (1982), there are four major kinds of advancing practices: promoting, demoting, transferring, and separating (p. 132):

- **Promoting** is moving to a higher job level. Promoted workers are usually given more responsibility. Higher level jobs often require more knowledge or skill. Promotions are given for doing good work. They very often mean more pay.
- **Demoting** is moving to a lower job level. This is the opposite of promoting. Demoting usually relieves workers of some responsibilities. . . . Sometimes demotions are given to discipline workers. Other times the work force has to be cut back. Or, maybe the nature of the work has changed.
- **Transferring** is moving a worker to a different job. The new job is at the same level and pay. Transferring may be done because the worker wants a change. . . . transferring is often the best way to fill new job openings.
- **Separating** may be discharging, relocating, or laying off workers. . . . Discharging means firing. . . . Relocating is changing a worker's site assignment. . . . Laying off is letting workers go temporarily.

Retiring is a special form of separating. Since construction workers change jobs frequently, they usually carry pension plans with their unions and not the companies that hire them. This way they maintain full benefits at the time of their retirement.

Financial Affairs

There are four major types of financial affairs in the construction system. First, working capital (money) must be secured by project developers. Next contractors (entrepreneurs who build projects) are required to submit bids which estimate how much money it would take for them to build the project. A construction firm is then selected and a formal contract and related paperwork is completed. Finally, construction materials needed to build the project are purchased.

Working Capital

Working capital (money) is needed by the owner or developer to purchase the site (property) where the project will be constructed. Money is also needed to finance the contractor who is selected to build the structure. Money is generally obtained from either private or public sources.

Private funds can be obtained from the owner, from investors, or from mortgage loans. Projects such as office buildings or manufacturing plants are considered private because there is a profit motive involved for those who provide the investment

money. "Public projects are funded by local, state, and federal taxes" (Henak, 1985, p. 46). Public projects such as schools, highways, and water treatment facilities benefit the general public.

Contracting

Once project plans and specifications are completed and funding has been secured, the owner/developer selects a contractor. This process, called contracting, involves the following specific steps (Lux et al., 1982, p. 107).

1. Advertising for bids
2. Supplying bidding documents
3. Opening bids
4. Awarding the contract
5. Bonding the contractor
6. Signing the contract (agreement)
7. Issuing a notice to proceed

These steps have been set-up in such a way that all contractors who submit bids should be given fair consideration. This process is also designed to ensure that the owner receives exactly what the selected contractor promises to deliver.

Contractors are usually given about 90 days to submit their bids in sealed envelopes. A bid is a contractor's estimate of the total cost that would be required to build the structure. Bids, which are prepared by estimators, include material costs, labor costs, equipment costs, overhead, subcontractor costs, and profit. Once the bids are opened, no additional bids will be accepted nor can previously submitted bids be changed. During public bid openings, every bid is read aloud for all to hear and anyone may examine any contractor's proposal (Lux et al., 1982, pp. 104, 108–112).

Generally, the contract is awarded to the contractor with the lowest responsive bid. "A bid is responsive if it matches all conditions contained in the bidding documents" (Lux et al., 1982, p. 104). The contract does not become final until "the owner gets the money to build and the contractor gets bonded" (Henak, 1985, p. 98).

Bonding is a kind of insurance to protect the project developer or owner. The contractor must acquire a performance bond and a payment bond before the contract to build the project is signed and work can begin. According to Lux et al., (19.,82, p 106):

- **Performance bonds** guarantee that contractors will follow plans and specifications. . . .
- **Payment bonds** guarantee that contractors will pay their subcontractors and suppliers. (Sometimes the bonds even guarantee that contractors will pay their employees.)

Therefore, contractors who fail to follow specifications or fulfill the contract will be replaced. The bonding company is responsible for paying another contractor to do the job right. Further, if subcontractors, suppliers, or employees are not paid by the contractor, the bonding company must do so. Once the contract is signed by both parties and the bonding is confirmed, the owner issues a notice to proceed and work begins.

Purchasing Materials and Equipment

The purchase of materials must be planned early so that stock-outs (shortages) will not occur to delay production schedules. Purchasing actually begins as soon as notification is received that the contract has been awarded. Contractors can secure materials from any of five possible sources. "They can get them from stock, buy as needed, buy with lump sum contracts, use a job account, or let a subcontractor buy materials" (Henak, 1985, p. 121).

Materials would be obtained from stock if a surplus exists there from other projects. This practice is acceptable as long as the stock materials meet current project specifications.

Contractors most often buy materials from vendors as needed. The material is purchased "just in time" for use. Most contractors keep their inventory at minimum levels so that inventory storage and handling costs as well as losses due to theft or damage can be kept as low as possible.

Purchase requisitions are completed by a superintendent when materials are needed. Office workers prepare and send purchase orders to vendors who supply the material. When the vendor delivers a shipment, a bill of lading (list of items) is checked against the shipment and a quality inspection is performed before the bill of lading is signed. Claims are filed for shortages and low grade materials are not accepted. The vendor then sends an invoice (bill) and the home office pays the bill (Henak, 1985, p. 122–123).

When lump sum contracts are employed, large quantities of materials are purchased and received by a central supply facility that the construction firm owns. Material orders from various projects that the firm has contracted with are received and filled from the central supply facility as needed. Quantity discounts for materials can be provided by vendors and better control of materials can be maintained when lump sum contracts and central

supply facilities are employed.

A job account is money (cash, checking, or credit) that is available to a project superintendent to pay bills that must be attended to immediately. This money might be used to pay for material shipping costs, severance pay for workers who quit or are fired, or the purchase of materials that are needed right away.

Equipment is usually purchased by the construction company for big projects that will require long term use. Equipment can be rented when short term use is anticipated or when an immediate need exists. "It may cost less to rent equipment you need right away than to wait for a purchase. The cost of delay in the schedule may be more than the rental fee" (Henak, 1985, p. 124).

Structural Production

Many kinds of building, nonbuilding, and transportation surface projects are built in the construction system. Some projects such as dams and skyscrapers are very large. Others such as residential homes and sidewalks are small. However, regardless of size or complexity, all construction projects are built using the same general procedure as outlined by Lux et al., (1982, p. 17):

1. The site is prepared by clearing away all unwanted objects. The site is surveyed to locate the exact place for the structure. Then earthmoving is done to reach the surface on which the structure will rest.
2. The foundation is set below the ground level. It is called the substructure. The substructure will bear the weight of the whole structure.
3. The superstructure is built on the substructure. Buildings are enclosed to keep out the weather. Some structures, such as bridges and roads, are not enclosed.
4. Utilities are installed to provide light, water, [communications (telephone)], heat, and cool air. This requires wiring, plumbing, and ductwork.
5. The interior of the structure is enclosed (in a building). Inside surfaces are covered to hide utilities and improve appearance.
6. Surfaces are finished to protect the materials and improve their appearance. This mainly involves painting and decorating.
7. The site is landscaped by smoothing and shaping the land surface. A lawn, trees, and shrubs may be added.

Within each of the seven structural production steps above, the forms of materials are significantly changed to increase their economic value. Material forms are changed through three major production processes: forming, separating, and combining.

Material forming occurs when construction materials are cast/molded, compressed/stretched, or conditioned. Casting/molding processes may include pouring concrete into wooden or metal footer forms, backfilling earth on the foundation of a building, or brush finishing the surface of a concrete sidewalk. Compressing/stretching processes may be involved in bending wire reinforcing mesh into position for pouring concrete slabs, contouring water piping or electrical conduit along walls or ceilings, or installing ductwork for air circulation systems. Conditioning processes change the internal structure of materials. Examples might include heat treating metals or curing liquid forms of plastic or concrete.

Separating processes occur when materials are sheared, chips are removed, or other processes. Material shearing processes include cutting metal ductwork, roof shingles, or vinyl siding with knives or shears. Material chip removal processes include any sawing, drilling, scraping, or digging operations. Other separating processes may include induced fracture cutting of glass or ceramic tile, thermal oxy- acetylene cutting of structural steel members, and chemical etching on metals.

Combining processes occur when materials are mixed, bonded, coated, or mechanically fastened. Material mixing occurs when preparing concrete with sand, gravel, and cement. Bonding processes may include those that are cohesive (such as welding steel structures together), or those that are adhesive (such as using mortar to lay blocks/bricks, or gluing floor or wall tile in place, or applying wallpaper). Coating processes may include applying filler to joints in plasterboard or painting inside and outside surfaces for protection and decoration. Finally, mechanical fastening processes include nailing wood frame members together, stapling insulation or roof shingles in place, screwing electrical fixtures in place, riveting structural steel members together, and many others.

Marketing

The marketing area of a construction firm has two major purposes: to promote the firm's public image, and to display structures that the company

has built for others. Marketing activities are especially useful during the contracting and bidding phase of construction. "Marketing people try to convince project planners/owners that their firm is the best one to build the project" (Henak, 1985, p. 104).

The Manufacturing System

The manufacturing system represents the ways that humans use system inputs to produce goods (output) in a factory. The key that distinguishes industrial manufacturing activities from industrial construction activities is that manufacturing activities take place in a plant rather than on a construction site. The system inputs (resources) are transported to a central plant location where products are typically mass-produced (multiple copies of the same product) compared to the custom production of one-of-a-kind construction projects.

Humans have been manufacturing products since "early man chipped pieces of stone into weapons to defend himself and to hunt animals for food" (Lux et al., 1971, p. 9). For centuries prior to the first industrial revolution (1700's), products were custom produced in small shops or homes by highly skilled craftspersons. These individuals generally produced the whole product from start to finish with hand tools operated by human power.

During the first industrial revolution, product manufacturing was moved to factories where machinery powered by engines was used to mass-produce products (Lux and Ray, 1971, p. 13). A division of labor with work specialization was developed to increase production efficiency so greater quantities could be produced in less time at a lower unit cost to consumers.

The second industrial revolution (1900's) has more recently brought about greater control of machines and production systems by computers and robots. Flexible manufacturing systems using group technology, automated work cells with robots and computer numerically controlled (CNC) equipment, and automated warehousing and delivery of supplies characterize the more advanced manufacturing systems that exist today.

Lux and Ray (1971) have listed examples of two basic kinds of products that can be produced by the manufacturing system (p. 412).

They state that durable products are those designed to last three years or more while nondurable products do not generally last three years. The common processes (unifying themes) that are used to produce any of these two types of products can be designed into relevant content and activities for studying the manufacturing system.

The illustration below shows the major elements in the manufacturing system. Since system inputs have been previously addressed, the primary focus of the following discussion will be on the manufacturing process area.

Durable Products	Nondurable Products
Farm Trucks	Food
Stoves	Clothing
Pianos	Light Bulbs
	Pencils
	Floor Wax

Ownership and organization, research and development, industrial relations, financial affairs, production, and marketing are common process areas which employ activities that can be used to manufacture any kind of product (Colelli, 1986, pp. 4–6).

Ownership in Manufacturing

Several forms of ownership are available in the manufacturing system, each with advantages and disadvantages. Included are a) the individual proprietorship, b) the general partnership, c) the limited partnership, d) the cooperative, and, e) the corporation (Amrine et al., 1982, p. 455).

Individual Proprietorship

The individual proprietorship is "a business enterprise totally owned by one person" (Wright, 1984, p. 96). Proprietorships are considered the oldest and simplest form of ownership. The proprietor can

easily start the business, has complete control over all activities, keeps all profits, has complete privacy of all records, and can easily liquidate the business if desired. Some disadvantages of this form of ownership are that it is difficult to raise large amounts of capital, not every proprietor is qualified to handle problems that can occur in specialized areas (i.e., production, finance, marketing, etc.), and the owner must assume personal liability for all debts incurred by the business.

Partnerships

A general partnership "is an association of two or more persons to carry on a legal business as co-owners for profit" (Amrine et al., 1982, p. 456). Like the proprietorship, the partnership is easily started, is under complete control of its owners, returns all profits to the owners, allows privacy in records, and is easy to end. A further advantage is that greater capital can be generated from the personal savings of more than one owner. The disadvantages of the partnership are that the owners are subjected to unlimited personal liability for all the debts of the firm. Partners must also be able to get along with one other. (Wright, 1984, pp. 98–99)

Limited partnerships were designed to overcome the disadvantage of unlimited liability on each partner. According to Amrine et al. (1982) the limited partnership is "an association of one or more general partners who manage the business and one or more limited partners whose liability is limited to the capital they have invested in the business" (p. 458). Profits are shared by all partners; however, unlimited liability is shared only by those general partners who make the day-to-day decisions necessary to manage the business. The primary advantage of this form of ownership is the ability to attract money from investors who do not desire to be held liable for management decisions.

Cooperatives

The cooperative is a form of "private owner-

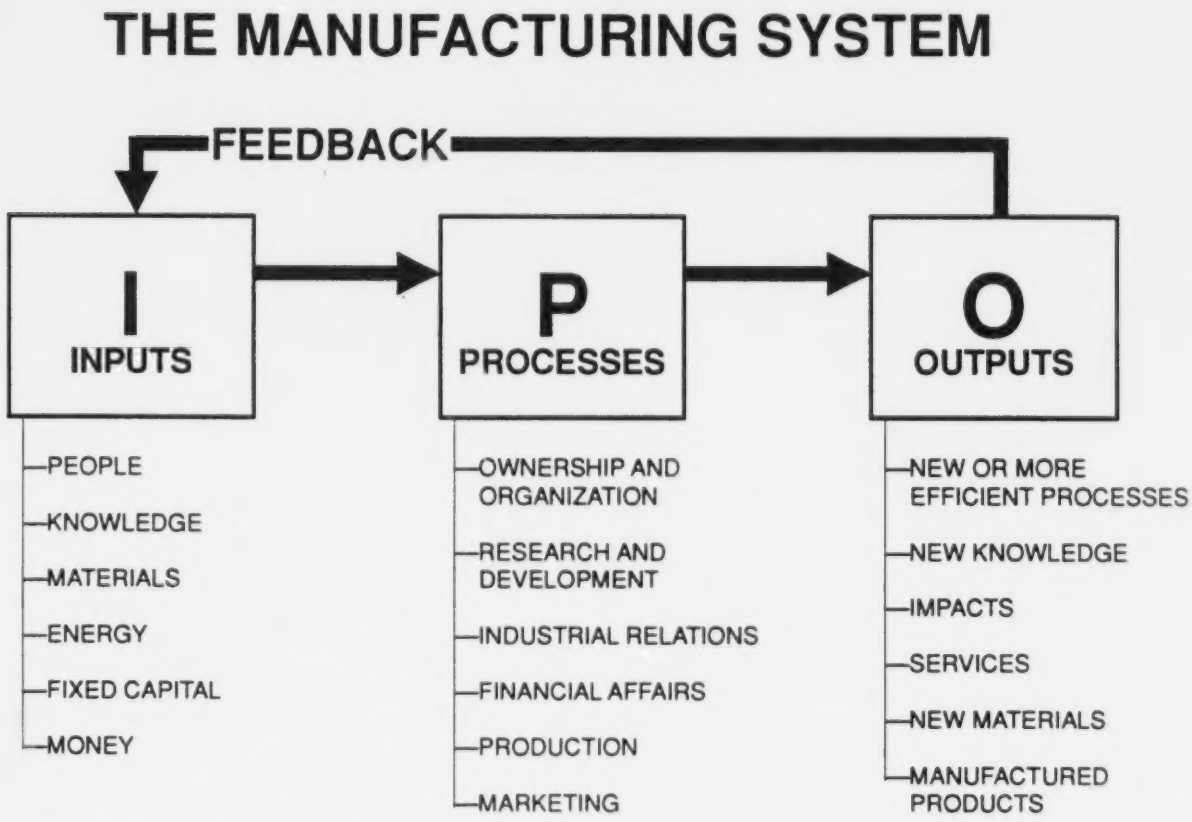


Figure 5: The Manufacturing System

ship" where the primary goal is to "eliminate profit and thereby provide goods and services to members . . . at cost" (Amrine et al., 1982, p. 458). Each member is a part owner of the company, generally a corporation, or incorporated business. But unlike other forms of ownership, in a cooperative each member has only one vote—rather than voting in proportion to the percent of ownership. The cooperative is generally run by elected officials such as a board of directors.

Cooperatives exist for individuals (consumer cooperatives). These generally deal in retail trade and services such as food, clothing, furniture, and credit (credit unions). Some businesses (both large and small) have established cooperatives (producer cooperatives) "organized for group buying and selling of items such as fruits, grain, or livestock" (Amrine et al., 1982, pp. 458–459). Producer cooperatives also supply credit, oil refinery services, dairy processing to name a few.

Corporations

Over three-quarters of the businesses in the United States are organized as corporations (Fales et al., 1986, p. 108). This form of ownership was developed to legally separate personal property of owners from the property of the company, and to provide a means to obtain large amounts of money to build and equip manufacturing plants. According to Lux and Ray (1971, p. 40):

> This form of ownership creates an artificial person whose rights and responsibilities are defined by law in its charter. All corporations must receive a charter (written permission) in order to come into existence. The charter states what the corporation will produce and how much stock (amount of ownership) it will sell to persons who wish to become stockholders. The amount of ownership a stockholder purchases is shown by the number of shares (units of ownership) on a stock certificate.

This so-called "artificial person" (the corporation) can enter into contracts, sue or be sued, and pay taxes (Wright, 1984, p. 100).

The owners (stockholders) of the corporation elect a board of directors who are charged with the responsibility of running the enterprise. The board of directors elects officers to make day-to-day decisions necessary for the efficient operation of the company. Stockholders periodically receive a share of profits in the form of dividends.

The primary advantage of a corporation is the limited liability of its owners (stockholders). Stockholders are legally liable only for the amount of money that they invest. As an artificial person, the company can be sued and may be obligated to pay for damages incurred or debts due from company-owned assets. The stockholders (owners) and managers do not have to pay debts or unfavorable court settlements out of their own personal property and savings as is the case with proprietorships and partnerships.

Another advantage of the corporation is its stability and longevity. This "artificial person" cannot die of natural causes because it is not physically alive like humans. If owners or managers die, the company does not have to be liquidated; they are simply replaced. Further, ownership (shares of stock) can be transferred without affecting the operation of the company.

The limited liability and transferability of shares make it much easier for this form of ownership to raise large amounts of money from private investors. The characteristics of stability and longevity make it much easier to raise capital from banks, insurance companies, and other lending institutions.

A final advantage of the corporate form of ownership is that the activities of many uniquely different manufacturing process areas (R&D, Finance, Marketing, Industrial Relations, and Production) are not left in the hands of one or even a few individuals who cannot effectively handle all the problems and operations of these highly specialized areas. Corporate organization requires a highly competent management team to plan, organize, direct, and control corporate activities within all process areas.

One major disadvantage for corporate organization is the great quantity of paperwork for taxes, quarterly reports, and others that must be completed. Another disadvantage is the fact that the corporation's income is subject to double taxation. "It is taxed first as income to the corporation. Then, as profits are paid out, they are taxed as personal income to the individual stockholders" (Amrine et al., 1982., p. 459).

Organization in Manufacturing

A manufacturing organization is an association of people working together as a team to obtain the goals of an enterprise. The most common basis for subdividing (organizing) enterprise activities is by function such as research and development, industrial relations, finance, production, and marketing. Some companies also subdivide activities by

Stockholders	Owners: Ultimate Control Over The Enterprise
Board of Directors	Forms Policy—Gives Direction
President	Immediate Control Of All Activities
Vice-Presidents	Control A Major Activity Such As Marketing, Production, Etc.
Plant Manager	Controls A Manufacturing Facility
Department Head	Coordinates A Segment Of Total Plant Activity
Supervisor	Supervises Workers
Worker	Performs Work Outlined By Management

process (drilling, plating, bleaching), equipment (drill presses, milling machines, etc.), location (northern division, western division), product, and/or class of customers (retail, wholesale, industrial) (Amrine et al., 1982, p. 47).

Distinct levels of authority exist within any manufacturing organization. Wright (1984) illustrates the levels of authority from the owners down to those who do the work.

The figure represents the simplest form of organization: the straight line.

Line Organization

Line organization occurs when "the positions listed on the organization chart are in a vertical line" (Amrine et al., 1982, p. 50). With this form of organization, the individuals in each line position have no staff to aid them and therefore must handle all problems that arise within their respective areas.

Line and Staff Organization

Another form of corporate organization, called line and staff, allows the addition of some specialists to relieve the burden on the line personnel. According to Amrine et al. (1982), "It would be impossible for a company of any size to use a pure line type of organization, for no one person possesses the ability to manage all the various functions that must be performed in a diversified business." (p. 51) Generally, staff people study situations and make recommendations to superiors. Superiors make decisions and give orders.

Incorporation

Once a group of individuals decide to start a corporation, they must follow a series of steps to obtain a charter so that the new company can do business. They must identify the purposes of the corporation, pick a location for a home office, and then choose a name for the corporation. This information is submitted to an appropriate state agency (generally the office of the Secretary of State) on a document titled Articles of Incorporation. In most instances, a logo (trademark) is designed as a graphic identification of the company and for marketing purposes.

Bylaws

After the charter is approved by state officials, the board of directors meets to work out the bylaws of the company.

> The bylaws state the regulations (rules) of the corporation. They state how the business will be run. They must conform (agree) to the charter and to state laws (Lux and Ray, 1971, p. 431).

According to Wright (1984, p. 101), some common provisions of corporate bylaws include:

1. Date and place of the annual stockholders' meeting.
2. Date and place of the board of directors' meeting.
3. List of top corporate officers, their duties, terms of office and method of selection or election.
4. Number of people on the board of directors, their terms of office, powers and pay.
5. Method of changing (amending) the bylaws.
6. Types of proposals that must be approved by the stockholders before they become corporate policy.

Research and Development

Research is the activity of seeking knowledge and development is the activity of applying knowledge to solve problems. Individuals who work in the research and development area of a manufacturing company may seek information (research) about "(1) materials, (2) products, (3) processes, and (4) consumer demand." They may then apply this knowledge to develop "(1) new and better materials, (2) new and more desirable products, (3) new and more efficient processes, and (4) new and bigger markets" (Ray, 1975, p. 12).

Research

Research can be conducted in three basic ways. Historical information (about materials, products, processes, or markets) that was discovered through past experiences can be retrieved from storage facilities such as libraries. Current information can be described through audio, visual, or written reports, and surveys. Finally, new information can be generated through a process called experimentation. (Lux and Ray, 1971, p. 53).

When any of these three research processes are carried out just for the personal desire to know the information or to add some new knowledge to the already existing body of knowledge, this activity is referred to as basic or pure research. "Applied research activities are designed to gain and apply knowledge to [solve] specific problems facing the enterprise" (Wright, 1984, p. 126).

Development

Development activities (whether they focus on materials, products, processes, or markets) usually involve two major steps: a) design, and b) engineering. Since most educational experiences designed to teach the concept of development typically focus on products, design and engineering activities related to product development will be discussed below.

Product design usually starts with an idea. Once an idea is brought to mind, a product designer conducts research to obtain as much information (knowledge) about similar products and how they function as possible. Alternative design solutions can be recorded and presented by two-dimensional sketching and rendering. The design solutions can be further refined through the construction of three-dimensional models (mock-ups).

Two-Dimensional Design

Sketching is referred to as a process of presenting two-dimensional design solutions. Thumbnail sketches are small quick pencil sketches "almost a doodle" that show very little detail. Their major purpose is to help the designer quickly record ideas before they are forgotten. One thumbnail or parts of several thumbnails may be combined into another kind a sketch called a rough. Rough sketches are larger, show more detail, are also done "rather quickly and may have suggestions about color and material." (Lux and Ray, 1971, p. 67).

> Most design offices do not [initially] ask for very detailed sketches. What they want is a quick sketch that tells the story simply. When final presentation . . . [to top management and engineering] is made, a very careful sketch is made. This kind of sketch is called a rendering (Lux et al., 1982, p. 68).

Renderings show a great amount of detail and color. They actually look like a final product in two-dimensional format.

Three-Dimensional Design

Two-dimensional design solutions can be further developed by the design team into three-dimensional models. Three major types of three-dimensional models are paste-up mock-ups, appearance mock-ups, and hard mock-ups. Mock-ups are more complex and expensive to construct, but they provide a better way to communicate alternative design solutions.

The paste-up mock-up is a very rough model using inexpensive materials such as cardboard, glue, tape, and paper. The major function of this type of model is to provide product developers with their first three-dimensional glimpse of product size, proportion, and balance.

Appearance mock-ups attempt to show what the final product design will look like. Colors are added and simulated materials may be used to represent actual product materials (for example, silver paper may be used to represent chrome). Devices such as knobs and switches are also represented, but they do not function.

The hard mock-up, made of wood and metal, is a further refinement of three-dimensional modeling. This model may be made of actual product materials and may include external working knobs, lights, handles, doors, etc. However, the internal mechanics or electronics of the product do

not exist. "The hard mock-up is used for final explanations, consumer surveys, photography for advertising, market explanations, engineering studies, producibility studies, and further design improvement" (Lux and Ray, 1971, p. 69).

Market Research

Product designs can be further improved by obtaining information from consumers. This is accomplished through the use of opinion generating instruments called consumer surveys. Consumer surveys provide product designers with much needed information about "consumer acceptance (whether people will buy)" (Lux and Ray, 1971, p. 77). Any suggestions for improvement of the product by potential consumers are considered before product engineering and full scale production begin.

Product Engineering

Product engineering converts a product design that was approved by management into working drawings and detailed part/material specifications. A working model (prototype) of the product is built and tested. Design errors found in the prototype can be corrected by modifying (changing) the design or improving the drawings. Finally, technical writing and illustrating processes can be employed to prepare instruction manuals, service information guides, and product warranties.

Industrial Relations

People are considered the most important resource in modern manufacturing. Their physical and psychological well-being is vital to the efficient and successful operation of any enterprise. The industrial relations area of the manufacturing system is designed to promote good relations between the company and the people with which it interacts: its employees, its organized labor, and the general public.

Employee Relations

Employee relations involve processes which hire and train personnel, determine wages and salaries, provide a safe work environment, advance employees, provide employee services, and promote effective communications (Wright, 1984, p. 163).

Employees in the manufacturing system are hired in much the same manner as those discussed earlier in the construction system. Workforce needs are determined, potential workers are attracted (through various forms of advertisement), information is gathered (through applications, testing, references, and interviews), and qualified individuals are selected for employment.

Training

Employee training can take place through a variety of programs. On-the-job training, the "most effective and popular," requires the employee to "learn by doing." Classroom training is designed to "handle a maximum number of trainees with a minimum number of instructors" for "large-scale instruction." Apprentice training (as previously discussed in the construction system) is designed to prepare individuals for "highly skilled work."

Machinists, electricians, or tool-and-die makers are usually prepared through apprentice training. Cooperative training can occur when high school or college students "spend part of their time in a practical job experience and part of their time as students in school." Students gain practical experience and good contacts for employment upon graduation.

Finally, vestibule schools can be set up to train "large numbers of workers" in "similar skills . . . quickly and uniformly." Equipment is set up to duplicate a production facility as closely as possible. Mistakes will then have no effect on actual production and employees can be "transferred to the production floor where they can take over a regular job with a minimum of delay" (Amrine et al., 1982, pp. 360–363).

Management training is usually referred to as executive development. Management personnel are often encouraged and paid to attend schools where they learn new management techniques. Further, attendance at special seminars, conferences and lectures is expected. Managers may also be trained by rotating them for short periods through a number of jobs "to provide a big picture of the department, area or company" (Wright, 1984, p. 169).

Wages and Salaries

Employee wages and salaries are determined through an orderly step-by-step process. First, existing jobs are analyzed to determine the type of skills and knowledges that are needed to perform the job. Next, all jobs in the company are carefully compared and grouped (rated) on the basis of their difficulty or on the demands they make on skill or energy.

A pay scale is then developed based on job rat-

ing information with higher pay going to jobs that are more difficult or require more demands on skill or energy. Performance standards are developed for each job so that workers can be evaluated. Those who work quickly and accurately may be rewarded with bonus pay ("pay for production above standard performance levels") or promotion. Finally, a system of keeping records is established to keep an accurate account of time, production, or other pay-related information. This process is referred to as "wage control" (Wright, 1984, p. 166).

Health and Safety

Health and safety of employees are big concerns of employers since workers must be in good physical condition to work at their top level of efficiency. According to Amrine et al., (1982), accidents are caused by either unsafe acts or unsafe working conditions. Unsafe acts occur because "of the employee's ignorance or forgetfulness or because he deliberately took a chance" (p. 368). Unsafe conditions are "those situations in our physical environment" (broken safety guard, leaking acid valve, etc.) that could cause accidents" (p. 368). Hopeman (1980, pp. 188–189) states that:

> Industrial accidents result in a great loss to a company as well as to the employee. Medical costs, in many cases, are borne by the company. Costs of damage to machines, lost production, and damaged products are also factors. A large number of industrial accidents in a company tends to increase insurance rates.

Since these costs can be very large, most companies have developed formal safety programs coordinated by either a safety director or safety engineer.

The passage of the Williams-Steiger Occupational Safety and Health Act of 1970 (OSHA) has also led to increased emphasis on safety. Rather severe penalties have been mandated for the employer when OSHA inspectors find violations of the standards established by the act.

According to Amrine et al. (1982), an analysis of most successful safety programs will disclose that they contain the four E's—Engineering, Education, Enlistment, and Enforcement. Engineering means that machines and jobs are designed to be safe with proper guards and safety equipment provided to workers. Education involves alerting employees to hazardous conditions through formal ongoing training programs. Enlistment means getting employees actively involved in safety practices through "safety meetings, safety posters, safety contests, safety films, safety committees, and numerous other devices" (Amrine et al., 1982, p. 366). Finally, effective enforcement occurs when management supervises the adherence to safety rules and deals with violators according to stated policy.

Benefits and Services

Employee benefits and services are considered "extras" that result in financial gain to employees above their wages or salary. According to Wright (1984, p. 170):

> Benefits are programs offered by the company which give direct financial (money) help to the employee. This aid is not included in the paycheck. . . . Benefits may include insurance plans, vacations and holidays with pay, retirement plans and unemployment insurance. . . . Services are cultural, social or recreational programs operated by the enterprise. Such services might include parties, dances, intercompany sporting events and games, company sponsored musical groups, discount tickets to sporting and cultural events and cafeteria facilities.

Benefits and services are usually obtained through collective bargaining contract negotiations with labor union and management representatives.

Communication

Communication is the final function of employee relations. An effective communication system allows employees to easily exchange ideas and reduce the likelihood of mistakes resulting from misunderstandings and lack of information.

Downward (vertical) communication from management levels to the workers is promoted through company newspapers, magazines, bulletin boards, and other notices. Upward (vertical) communication is promoted by using a suggestion system which may reward employees for cost-saving ideas. Horizontal communication "allows for exchange of ideas and solutions involving similar work and problems" (Wright, 1984, p. 171). Horizontal communication is encouraged through seminars, conferences, and the use of memorandums.

Labor Relations

Labor relations involve conditions of employment that are arranged between an employer and organized groups of employees. Generally, the study of labor relations can be organized into three distinct areas: a) union organizing activities, b) col-

Step Number	Union Representative	Employer Representative
1.	Employee or steward, or both	Foreman
2.	Chief plant steward	Superintendent
3.	Plant grievance committee	Plant manager
4.	National union representative	President of company
5.	Arbitration	

lective bargaining, and c) grievance procedures (Wright, 1984, p. 172).

Union organizing activities may include an analysis of the different types of labor organizations that represent manufacturing workers. Also included would be a look at the organizational structure of most unions including the national organization and its constitution, the local union and its charter, and the responsibilities of important local union officials such as the business agent and the union (shop) steward. Characteristics of different forms of union security (such as closed shop, open shop, exclusive bargaining shop, agency shop, union shop, and others) can also be examined.

Collective bargaining (as previously stated in the personnel relations section of the construction system) is a process of arranging working conditions, wages, and benefits through group representation as contrasted to "individual bargaining." According to the law, management and labor unions must bargain in "good faith" with proposals and counterproposals until an acceptable compromise can be reached by both sides. When workers vote to accept (ratify) a union/management agreement, it becomes a legal binding contract.

A grievance procedure is usually established to solve misunderstandings between labor and management. Amrine et al. (1982, p. 398) illustrate five steps involved in a typical grievance procedure.

Economic weapons of the union and company that can be used to bring pressure on the other side when grievances cannot be resolved or contract agreements cannot be reached (as discussed in the personnel relations section of the construction system) can also be studied.

Financial Affairs

The financial affairs of a manufacturing enterprise includes processes used to obtain money (finance), to control money, and to purchase tools, equipment, and materials needed in the production area. Therefore, the three functions of the financial affairs activity area in manufacturing are finance, control, and purchasing (Wright, 1984, p. 177).

Finance

Money may be obtained (financed) from a variety of sources such as personal savings, loans, sale of securities (stocks and bonds), trade credits, and profit plowback. (Amrine et al., 1982, p. 474). The study of finance in an educational setting may involve identifying and describing advantages and disadvantages of different sources of money as well as procedures that can be used to obtain money. This information can provide valuable consumer insight for students to later use in their own personal financial dealings.

Control

Financial control means making estimates of costs, allocating money, and keeping records of expenses. According to Amrine et al. (1982, pp. 333–334), typical cost elements of a company may be divided into three categories:

1. **Materials**
   a. Direct—Materials that directly become part of the product itself.
   b. Indirect—supplies used to help process the direct materials (light bulbs, cleaning rags, sandpaper, and hand tools).
2. **Labor**
   a. Direct—Labor used to supervise or actually produce the product.
   b. Indirect—Labor such as maintenance, clerical, and plant custodial which is not directly related to material processing.
3. **Overhead**
   a. Production—All production costs excluding direct labor and direct material (indirect labor, indirect material, insurances, utilities, and others).
   b. Other—Management, advertising expenses, etc.

Cost estimates for the above categories are very important for determining the selling price of products and for allocating money (budgeting) to different departments.

Budgets are established as overall plans for controlling operations within each department as well as the whole company. Budgets act as "a

coordinating device among the various functions of the business" (Amrine et al., 1982, p. 340). Each department knows exactly how much money they have been allocated and expenditures that fall outside budget estimates can quickly be identified so that corrective action can be taken as necessary. A master budget summarizes all the more detailed department budgets. "It is used by upper management to get an overview of the company's financial picture" (Wright, 1984, p. 181).

Accounting is a form of financial control designed to keep records and compute the financial position of the company at any given moment. The responsibilities of accountants include maintaining company ledgers through a process generally referred to as bookkeeping. Ledgers are used by accountants to keep track of sales, loans, purchases, wages paid, and others. They are also responsible for preparing financial reports such as breakeven charts, balance sheets, income (profit and loss) statements, and the annual stockholder's report.

Purchasing

Purchasing (sometimes called procurement) is a procedure that is followed to obtain materials or parts needed for production.

> The right material of the right quality must be bought from the most economical (cheapest) source. This material must be supplied, delivered, or received in the right quantities to the right place at the right time (Lux and Ray, 1971, p. 185).

Usually individuals who work in purchasing select sources of supply (vendors), negotiate delivery and payment arrangements with vendors, and follow up delivery promises.

Most purchasing activities follow a standard procedure. A purchase requisition prepared by the department needing an item to be purchased is sent to the purchasing office. A request for bid or quote is then sent from purchasing to several vendors. Quotes or bids are received from vendors and evaluated by the purchasing office. A vendor is selected and a purchase order is sent to order the needed item. An invoice prepared by the vendor is sent to the accounting office requesting payment after the item has been shipped. When the item has been received and inspected, a receiving report is sent to the accounting office notifying them that the item has arrived in satisfactory condition. Finally, a payment check prepared by the accounting office is sent to the vendor to pay for the item that was ordered and delivered (Wright, 1984).

Production

Individuals who work in the production process area of the manufacturing system have the primary responsibility of producing products. When products are produced, a phenomenon known as "form utility" takes place within the production area of the manufacturing system just as it does within the structural production area of the construction system. "Form utility" means that the economic value of materials is increased by significantly changing their forms. Products made from these materials can then be sold at a profit.

Primary and Secondary Industries

Lux and Ray (1971) outlined a general procedure (referred to as stages of production) that is followed by manufacturers to bring about "form utility" in materials when producing products. First, primary industries such as metals (steel, copper, aluminum, and others), textiles, dairy, lumber, and petrochemical obtain raw materials from the earth, sea, and/or air. Primary industries then convert (process or refine) the raw materials into standard forms of industrial materials such as pig iron (ingots), steel (rods, sheets, plates, bars, coils), fabric (threads or bolts of cloth), whole milk (pints, quarts, half-gallons, gallons), lumber (sheets, boards), paper (skids, rolls, reams), plastic (pellets, granules, beads), and others. These standard forms of industrial materials can be used as consumer products or can serve as material inputs to construction or secondary manufacturing industries.

Secondary manufacturing industries convert standard shaped and sized industrial materials into consumer products such as televisions, kitchen appliances, telephones, automobiles, furniture, medicines, clothing, computers, and cosmetics. Standard stock from primary industries is first converted into single piece products or components of multiple piece products using material forming and separating processes which will be described later in this section. Components of multiple piece products are then assembled into sub-assemblies and final assemblies using material combining processes which will also be described later in this section.

Types of Production

All products are produced by one of three major production methods in the manufacturing system: custom production, intermittent production, and continuous production. According to

Wright (1984, p. 139) the method selected by a company generally depends on a ". . . careful study of three things:

1. Expected volume (number of products needed).
2. Product quality desired.
3. Equipment available."

Custom production is considered the oldest method of producing products. This form of production can be traced to the skilled work of master artisans from the first permanent societies in Egypt, Mesopotamia, India, China, Mexico, and Peru (Lux and Ray, 1971, p. 10). Custom production occurs when one or a small number of highly skilled individuals produce a product from beginning to end. Generally, simple machines or hand tools are used and a great amount of time is spent producing small numbers of high quality products. Custom production techniques are employed in contemporary industry to produce construction projects, manufacturing R & D mock-ups and prototypes, and manufacturing tooling (jigs, fixtures, dies, templates, patterns, etc.).

Continuous production is considered one of two major methods used by the manufacturing system to mass-produce products. This method is employed ". . . when large numbers of identical products are needed . . . . for a large and often unknown 'mass' market" (Wright, 1984, p. 139). Machines and workstations are generally set-up for only one type of product with materials moving continuously from operation to operation on a highly mechanized or automated line. Many times large expensive special purpose machines and tools are used. "Large food-processing plants, chemical plants, refineries, steel rolling mills, and other primary processing enterprises use continuous manufacturing" (Wright, 1984, p. 139).

Intermittent production is a second method employed by enterprises in the manufacturing system to mass-produce products. Intermittent production is often called "job-lot" production and a manufacturing firm specializing in this type of production is often called a "job shop" (Wright, 1984, p. 140). Job shops are set up with general purpose machines which are very flexible and allow many different products (jobs) to be produced at the same time in much lower quantities than in continuous production plants.

Materials are moved by lots (quantities such as 500, 1,000, 2,000) from operation to operation. An operation is performed on all parts in the lot before the lot is moved to the next workstation. Many metal and wood machining, and some printing facilities use the intermittent method of production. Also, large secondary processing enterprises often use combinations of continuous and intermittent production to mass-produce their products.

The production process area of the manufacturing system is composed of six major divisions of work. These are a) production planning and control, b) methods engineering, c) work measurement, d) plant (or facility) engineering, e) quality control, and f) material processing. Each division of work is strategically important to the successful production of products. Therefore, educational experiences should be designed to allow students some interaction in each of these six divisions so that they can gain insight into the gestalt of how products are produced.

Production Planning

Production planning involves preparing the product that was designed and engineered by the research and development group for either continuous, intermittent, or a combination of both forms of mass-production. The product is carefully analyzed and distinct sets of operations, transportations, delays, inspections, and storages are identified. Process flow charts summarizing individual parts and operation process charts providing a graphic summary of all product operations are developed. Finally, operation sheets are developed for each operation to provide detailed instructions to workstation operators.

Production Control

Production control involves establishing a system to insure that work is actually done according to established plans. According to Wright (1984), production control is divided into four phases.

1. Routing determines the path the product will take as it moves through the plant.
2. Scheduling determines when the product will be built and when each operation will take place.
3. Dispatching releases production orders. These tell the manufacturing manager when to start scheduled work.
4. Expediting (follow-up) determines if work is being completed on schedule. (p. 145)

Methods Engineering

Methods engineering is basically a search for better (more efficient) methods of doing things. This division of production activity is frequently referred to as "motion study," "operation analysis,"

"work study," or "job design" (Amrine et al., 1982, p. 109). Methods engineers examine existing or proposed methods of doing a job and try to develop better methods. The tools that they use include flow process charts, right- and left-hand simultaneous motion (Simo) charts, multiple activity charts, and an examination of motion pictures and videotape called micromotion and memomotion study (Amrine et al., 1982).

Work Measurement

Work measurement is commonly referred to as "time study." Individuals involved in work measurement are concerned primarily with determining the amount of time that is required to perform a unit of work. According to Amrine et al., (1982, p. 131), work measurement:

> . . . is used to determine the amount of time required by a qualified worker, using a standard method and working at a standard work pace, to perform a specified task. The time required for this task is commonly referred to as the "standard" or "allowed" time.

Standard times can be used in manufacturing to divide work into jobs to be done at each workstation, plan and schedule work for the plant, make cost estimates for new products, and establish wage-incentive plans (Wright, 1984, p. 144).

Plant Engineering

Plant engineering is a division of production work that involves selecting a plant location, designing and setting up the layout of the production facility, designing and installing materials handling devices, and preparing production tooling. Plant layouts are designed to provide good flow. "Good flow allows parts and products [and people] to move steadily through the plant" (Wright, 1984, p. 140). Good plant layouts shorten the time it takes to produce parts, subassemblies, or entire products. This can reduce costs and increase profits.

Materials handling has been defined by the Materials Handling Division of the American Society of Mechanical Engineers as ". . . the art and science involving the moving, packing, and storing of substances in any form" (Amrine et al., 1982, p. 155). Hopeman (1980) states that materials handling systems should be designed to a) move materials over the shortest possible distance, b) keep materials moving as much as possible (with short terminal times), c) carry materials both ways in materials-handling trips avoiding partial loads as much as possible, d) use straight lines of travel when possible, and e) include clearly marked labels on all materials so losses can be kept to a minimum (pp. 153–155). Materials handling devices include conveyors, cranes, elevators, hoists, fork lifts (jitneys), hand trucks, chutes, pipelines, automatic transfer machines, robots, and many others.

Tooling, as described earlier, includes devices such as jigs, fixtures, patterns, and templates placed on machines to help workers do operations efficiently. Tooling helps a) make parts more uniform (so they can be interchanged as needed), b) increase the speed of operations, and c) make operations safer (Wright, 1984).

Quality Control

Quality control is a division of production activity responsible for maintaining a certain level (standard) of accuracy among processes involved in producing products. Lux and Ray (1971) identify three main stages in a quality control system. These are "monitoring, reporting, and correcting" (p. 162). Materials are monitored (inspected) in three main locations: a) receiving, b) in-process, and c) end-process (Lux and Ray, 1971, p. 163):

> Receiving inspection makes sure that raw material and purchased parts fit production specifications. . . . In-process inspection includes all the inspections made during the manufacturing process. These inspections make sure that the product is good enough to be sold. . . . End-process inspection is the inspection that follows the completion of a manufacturing process.

After information is collected by inspection, it is compared to quality standards and reported to the production control team. If operations are being completed according to plan, no corrective action is taken. However, if operations are substandard, action is taken to find the problem and make corrective changes.

Material Processing

The sixth division of work in the production area of the manufacturing system is the actual processing of materials to make products. This can occur by forming, separating, or combining materials.

Material forming occurs when manufacturing materials are cast/molded, compressed/stretched, or conditioned. Casting/molding processes include

sand or die casting, dip molding, and slip casting. Compressing/stretching processes include forging, rolling, bending, vacuum forming, and glass drawing. Conditioning processes include heat-treating, mechanical deforming (cold-working), physical conditioning (i.e., magnetizing metals and baking foods or clay products), and chemical conditioning (curing thermosetting plastic resins to make them hard).

Material separating processes occur when materials are sheared, chips are removed, or other processes. Material shearing processes include slicing paper, punching holes in metal, or shearing metal/wood sheets. Material chip removal includes any sawing, milling, broaching, drilling, planing, jointing, routing, shaping or abrading operations. Other separating processes may include induced fracture cutting of glass or diamonds, thermal erosion by flame cutting, electrical discharge or ultrasonic machining of metals, electron beam or light (laser) beam machining of materials, or chemical etching.

Combing processes occur when materials are mixed, bonded, coated, or mechanically fastened together. Mixing occurs when chemicals are added to wood pulp to process it into paper, ingredients are compounded to produce drugs, or ingredients are mixed to form varieties of food delicacies. Bonding processes may include those that are cohesive (such as welding and brazing metals or ultrasonic welding of plastics) and adhesive (such as gluing, cementing or soldering parts together). Coating processes such as painting, plating and printing are designed to protect surfaces and communicate information. Finally, mechanical fastening processes include the use of nails, staples, threaded devices (such as screws, bolts, nuts, and pipe fittings), threads, straps, rivets, pins, keys, splines, wire, and hinges.

Marketing

All activities involved in transferring products from company ownership to consumer ownership are called marketing. Manufacturing marketing activity begins long before products are in the production stage. Product designers from the research and development process area work together with marketing specialists to provide an answer to the question: Will people buy this product?

Marketing activities are very important to high-volume continuous production enterprises where products have not been sold prior to production. Many intermittent production enterprises depend less on marketing because they produce products according to negotiated job orders.

There are five basic marketing steps or activities that must be carried out to market products successfully: market research, advertising, sales, distribution, and servicing. Market research must be carried out to determine "who and where the customers are; what they need, want, and will buy; where and how they will buy; and how much they will pay" (Amrine et al., 1982, p. 497). Advertising is conducted to promote the product, an idea, or the good name of the company. Selling involves an "actual exchange of . . . [product ownership] for money" (Wright, 1984, p. 158). Distribution moves the product from the producer to the consumer. And finally, product servicing makes certain that products continue to perform properly to the satisfaction of the customer.

Market Research

Market research is conducted in three basic ways: examining historical records, conducting consumer surveys, and through experimentation. Historical market research seeks information from the sales records of previous years to obtain data classified by territory, product, class of customer, salesperson, and more. Also, information about the characteristics of consumers can be obtained from the records of various governmental groups such as local chambers of commerce and trade associations.

Survey research is designed to obtain current information from potential customers concerning their a) reaction to the product, b) potential selling price, and c) intention to buy the product. (Wright, 1984). Care must be taken to ensure that those surveyed are representative samples of the actual population of consumers so that any information obtained will reflect the actual views of all consumers.

Experimental market research is designed to test the reactions of consumers to alternative marketing decisions. As in any experiment, all variables are held constant except the one under study. This way, any significant change in consumer behavior can be attributed to that variable. One example of experimental market research might be to change (vary) the height of the shelf location where the product is sold. Many stores have found that products sell better when displayed at eye level.

Advertising

Advertising is considered the information or

communicating arm of the manufacturing organization. Through advertising, potential consumers can learn the following information (Amrine et al., 1982, p. 502).

1. The fact that a product exists
2. Where it can be procured
3. What it will do
4. The price
5. How to care for it
6. How to use it
7. Probable length of life

Various forms of advertising media can be employed to carry an advertising message. According to Fales et al. (1986), newspapers provide immediacy, magazines provide permanence, radio provides drama, television provides action, and billboards provide impact. (pp. 161–163) Other forms of advertising media such as direct mail, the telephone, exhibits, contests, matchbooks, t-shirts, and ballpoint pens have been effective in getting the message out to consumers.

Product packaging is closely related to advertising. The product package is not only designed to protect a product, but also to promote the product and provide relevant information about the product.

Selling

Selling, as previously stated, is an actual exchange of product ownership for money. Selling requires direct contact between a salesperson and the buyer. Salespersons must be trained in correct and ethical methods of how to sell, about the features and operation of the product, and how to complete sales related paperwork (such as forms and receipts) (Wright, 1984).

Salespersons are usually assigned to geographic territories where they must contact potential customers and make sales. Most salespersons work on a commission. This means that a certain percentage of what they sell is paid to them. "The commission is an incentive (encouragement) to sell more products" (Fales et al., 1986, p. 165).

Distributing

Once products are sold, they must be distributed to buyers. Products can reach consumers through a number of distinct distribution channels. The most common distribution channel is from the manufacturer to the wholesaler to the retailer, and finally, to the consumer. (Fales et al., 1986, p. 165)

> Wholesalers buy large quantities of products at cheaper prices. Several railroad cars full of finished products may be sent to one wholesaler. The wholesaler, in turn, raises the price and then sells the products in smaller lots (amounts) to retailers. The retailers again raise the price and sell the products to the consumers. This practice of raising prices from one sales outlet to another is called marking up the product.

Alternative distribution channels might be from: a) producer to retailer to consumer, b) producer to wholesaler to consumer, and c) producer directly to consumer (Ray, 1975).

Servicing

Servicing products is an important manufacturing activity. Most products have a guarantee or warranty promising satisfactory performance for a certain period of time. Customers who have problems with products can be kept happy and satisfied when the company studies these problems and assists in their solution. These customers will likely continue to buy other products from the company in the future. Servicing is generally done "(1) to install a product, (2) to maintain it, (3) to repair it, or (4) to alter it to fit some special need" (Lux and Ray, 1971, p. 412).

The Transportation System

The transportation system represents the ways in which humans transport people and goods from one location to another. Moving people and goods represents a concept called "place utility" (Lux and Ray, 1969). The place or location of the item or individual is changed through processes that occur within the transportation system. One may recall from earlier discussion that another kind of utility called "form utility" takes place within both the construction and manufacturing systems when forms of materials are significantly changed to increase their economic value.

Throughout recorded history, human societies that have had the most advanced forms of transportation became world leaders in cultural and economic development. By 1500 B.C. the Greeks, with their merchant sailing ships, transported ideas and inventions from Egypt and other early river valley societies to many parts of the then known world. The Romans took over about 1,000

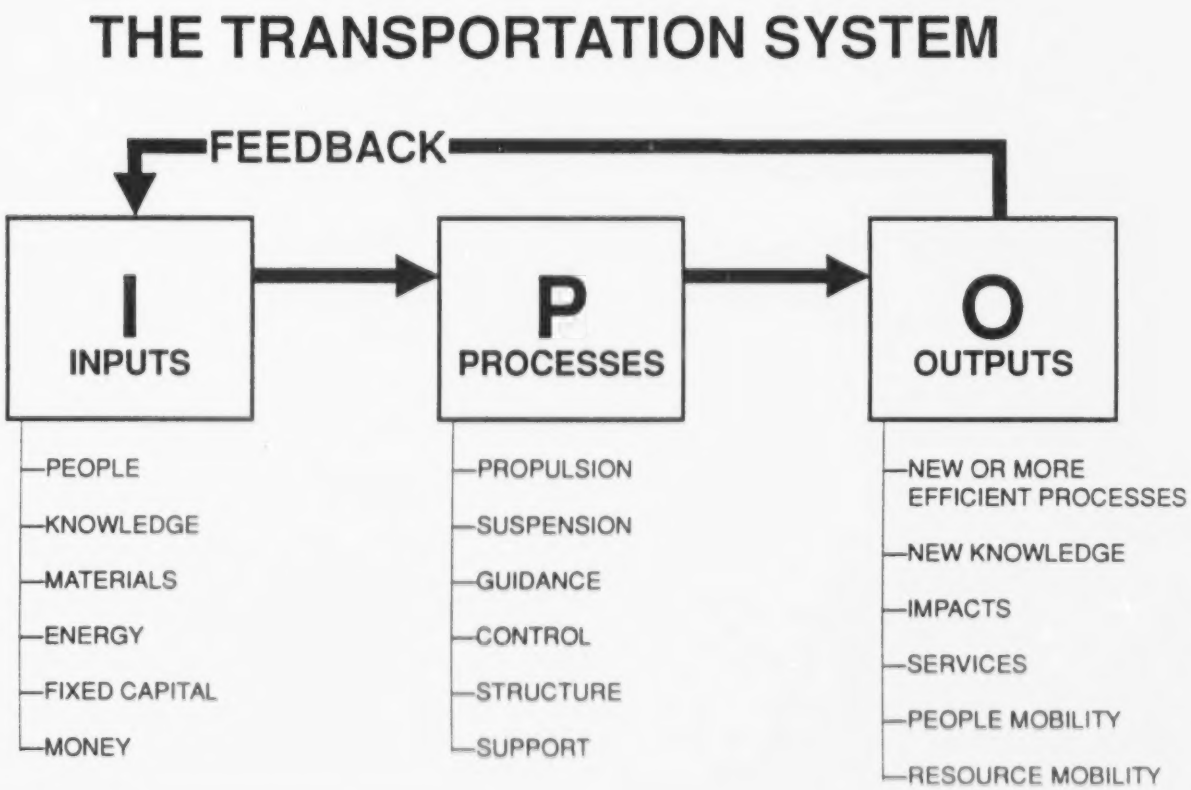


Figure 6: The Transportation System

years later where the Greeks left off. They built faster ships, good roads, and large bridges to shorten delivery time for people and goods. Their empire also lasted for over 1,000 years.

In more recent history, the British empire and their great naval fleet had a substantial influence on much of world politics until the United States and the Soviet Union assumed this responsibility after World War II. Today, the United States, the Soviet Union, Britain, France, Germany, and Japan lead the world in the most advanced forms of land, air, marine, and space transportation.

Most sources agree that there are four environments where transportation can occur: a) land, b) air c) marine (water), and d) space. Transportation vehicles are designed and built to operate efficiently and safely within one or more of these particular environments.

Environments

Land Vehicles

Land vehicles are designed to move people or goods along fixed or random routes along the surface of the earth. "Nearly all of the vehicles used in land transportation have wheels that roll over prepared roadways. . . . and much of this transportation is provided by the automobile" (Karwatka and Kozak, 1987, pp. 228–229).

Fixed route land transportation involves a direct route with few variations, if any, from origin to destination. Included are railways, escalators, elevators, cable cars, tubes, pipelines, and moving sidewalks. Random route land transportation vehicles are very versatile in that the paths from origin to destination vary according to human need or desire. Included are human locomotion, bicycles and motorcycles, automobiles, trucks, hovercraft, and snowmobiles (Bender, 1983).

Marine Vehicles

Marine vehicles are designed to move people or goods along inland or transoceanic waterways. Since over 60% of our planet is covered by water, marine vehicles (ships) have historically been considered a very important form of transportation.

Inland waterways may include canals, rivers, lakes, or coastal water. Inland waterway transportation vehicles may include barges, tow and tugboats, canoes, rafts, sail boats, hydroplanes, ferries, hydrofoil and hovercraft vessels. Transoceanic waterways include canals, oceans, seas, and straits. Transoceanic vehicles may include tankers, container ships, freighters, aircraft carriers, ocean liners, merchant ships, battleships, and submarines (Bender, 1983).

Air Transportation

Air transportation (sometimes called atmospheric transportation) is designed to move people or goods over long distances quickly using lighter-than-air and heavier-than-air vehicles. Lighter-than-air vehicles include gas filled and hot air type balloons and airships (non-rigid, semi-rigid, and rigid type). Heavier-than-air vehicles include conventional (fixed wing) and composite (rotary wing) aircraft (Bender, 1983). Air transportation is sometimes referred to as "atmospheric" transportation because these vehicles are designed and built to operate within (but not above) the atmospheric envelope that surrounds the earth.

Space Transportation

Space vehicles are designed to transport people or materials through and above the atmospheric envelope that surrounds the earth and other planets. Included are unmanned and manned vehicles. Unmanned vehicles include missiles (surface to surface, surface to air, air to surface, air to air), rockets, satellites, and space probes (lunar, planetary, and deep space). Manned vehicles may include launch, command, orbiter, re-entry, and laboratory vehicles (Bender, 1983).

The illustration shows the major elements in the transportation system. Since system inputs have been previously addressed, the primary focus of this discussion will be on the transportation system process area.

Propulsion, suspension, guidance, control, structure and support processes are used by humans to transport people and goods using vehicles that operate in land, marine, air, and space or combinations of these environments.

Propulsion

Propulsion means to create a force that will cause a vehicle (land, marine, air, space) to move to its destination. The study of propulsion in an educational setting should provide for a basic understanding of the following concepts: a) thrust and drag, b) power and acceleration, and c) efficiency of propulsion systems (Bender, 1983).

Thrust and Drag

Drag refers to frictional and gravitational forces that all vehicles must overcome when in motion. According to Bender (1983, p. 32):

> [Land] vehicles must overcome rolling friction of wheels and aerodynamic drag. Marine vehicles must overcome friction, wave and aerodynamic drag on superstructures. [Air] and space vehicles must overcome aerodynamic drag and also provide the lift needed to keep them in the air.

Thrust is the force provided by the vehicle to overcome the opposing drag forces so that movement can occur.

Power and Acceleration

Power is the amount of thrust that a vehicle is capable of applying. Power is directly related to the speed of a transportation vehicle. High power vehicles are capable of faster speeds than low power vehicles. The "rate of change of speed" that occurs when thrust is applied is called acceleration. Finally, the efficiency of a propulsion system can be defined as "the ratio of power output to [fuel] energy input . . ." (Bender, 1983, p. 32).

The study of propulsion in an educational setting should also provide content and activity experiences in the following three areas: a) energy source and storage, b) energy converters, and c) power transmission. A study of energy sources and storage methods can be designed to occur here in the transportation system or can be taught (as described earlier) as one of the six generic inputs to all four technology systems.

Energy Power Converters

Energy power converters are devices that turn energy such as petroleum based chemical fuels into the power needed to provide thrust for vehicle movement. A large number of energy conversion devices exist today and many more innovative devices are currently in the planning and testing stages of development.

The most common type of energy power converters are referred to by Bender (1983) as "heat [combustion] engines." Intermittent combustion engines that operate by spark or compression ignition include the Conventional Otto and the Stratified Otto as well as the Diesel engines. Continuous combustion can be found in the Brayton, the Rocket, the Rankine, and the Stirling engines. Additional types of energy power converters include electric systems, hybrids, and future power conversion systems such as the linear induction motor (LIM) and the flywheel propulsion system.

Electric power systems typically acquire electricity from rechargeable storage batteries to run electric motors. These devices actually convert electrical energy into mechanical energy to propel a vehicle. Hybrid propulsion devices usually involve a combination of a combustion engine as a primary source of power and a secondary electrical propulsion system operating from rechargeable batteries. Hybrids are usually designed to increase the overall operating efficiency and decrease the environmental polluting effects of vehicles.

The linear induction motor (LIM) operates exactly the same as a regular electric motor except that the windings are laid out flat instead of in a circle. According to De Old et al. (1986, p. 474) the LIM can be explained by comparison with a conventional electrical induction motor.

> The stator (stationary part) of a conventional induction motor uses . . . alternating current in a way that produces rotating magnetic impulses. The rotating magnetic impulses induce opposite magnetic impulses in the rotor (moving part). The rotor then follows the rotating magnetic field in the stator to produce [circular] motion for power.

The stator (stationary part or secondary coil) in a linear induction vehicle is anchored under the vehicle as a guideway or rail. The rotor (moving part or primary coil) is placed on the vehicle so that the electromagnetic force that is generated between the primary and the secondary coils will propel the vehicle in a linear direction along the secondary guideway.

Flywheel propulsion systems are designed to store kinetic energy and provide power while vehicles are in motion. The stored energy is applied to add thrust, conserve energy, and reduce environmental pollution of the primary propulsion system.

Power Transmission

Power transmission involves moving power from "its point of origin to its point of usage" (Bender, 1983, p. 35). The point of origin is the engine or motor and the point of usage may be wheels, propellers, screws, thrusters, or others. Mechanical power transmission (linear or rotary) is accomplished through the use of solid devices such as gears, belts, shafts, and rods. Fluid power transmission transfers power or motion by liquids (hydraulics) or gases (pneumatics) through enclosed

piping systems. Finally, electrical power transmission uses a flow of electrons (current) through electrical conductors or the flow of magnetic flux lines to transmit power.

Suspension

Suspension means to provide "support for the weight of a vehicle while allowing motion" to occur (Bolyard, 1986, p. 26). Well-designed suspension systems allow humans to travel in safety and comfort in land, marine, air, and space vehicles. Further, good suspension systems greatly assist shippers in their ability to transport materials or finished products to their destination in the same condition and quality that they were originally loaded.

The study of suspension in an educational setting should provide students with an understanding of three primary methods for supporting the weight of transportation vehicles: a) mechanical, b) fluid, and c) magnetic (Bender, 1983). Before proceeding to discussions of each of these suspension methods, it is important to note that some vehicles have primary and secondary suspension systems.

The primary suspension system is the one that was designed to suspend the vehicle in its operating environment (land, air, marine, or space). For instance, airplane wings provide primary fluid suspension in the air environment while wheels provide secondary mechanical suspension while taxiing and during takeoff and landing in the land environment. The discussion that follows will concentrate on examples of primary suspension as related to selected land, air, marine, and space vehicles operating in their particular environments.

Mechanical Suspension

Mechanical suspension systems are found predominantly in land vehicles. Examples of mechanical suspension include wheels, springs, struts, bearings, and torsion bars for automobiles and trucks. Wheels, spokes, and bearings on bicycles and motorcycles can also be included as well as rollers and belts on materials handling conveyor systems. Mechanical suspension also includes slideways for pneumatic tubes, which support money canisters at drive-thru banking outlets.

Fluid Suspension

Fluid suspension systems can be found in vehicles that operate in all four environments. Fluid can be defined as either a gas (called aero) or a liquid (called hydro). If the gas or liquid can hold or support the vehicle while it is in a stationary position, it is referred to as a aerostatic or hydrostatic suspension. If the vehicle must be moving through a gas or liquid to maintain suspension, it is then referred to as aerodynamic or hydrodynamic suspension (Bender, 1983).

Examples of aerostatic fluid suspension in land vehicles include air or other gas (such as nitrogen) shock absorbers in automobiles or trucks, air bearing materials handling devices for moving palletized materials, and air bag Personal Rapid Transit (PRT) vehicles. Air cushion vehicles that hover (hovercraft) at a stable height above the surface of land or water, are also considered examples of aerostatic suspension as well as lighter-than-air balloons and airships.

Aerodynamic fluid suspension is found primarily in air and space transportation vehicles through the use of airfoils. The horizontal stabilizer of the empennage (tail assembly) and the wings provide suspension for airplanes as they move through the atmosphere. Aerodynamic fluid suspension is also provided by the main rotor of a helicopter as well as the tail fins of rockets.

Wings and tail assemblies of space vehicles (such as the United States space shuttle) provide aerodynamic suspension during the flight through the atmospheric envelope which surrounds the planet. Once in outer space, there really is no fluid suspension system since the concentrated quantity of gases and fluids required for suspension do not exist in that environment.

Hydrostatic and hydrodynamic fluid suspension are found primarily in marine vehicles. Boat hulls are methods of hydrostatic fluid suspension in a marine environment as well as hydraulic (oil filled) shock absorbers in land vehicles. An example of hydrodynamic fluid suspension would be a marine vehicle operating on a hydro-foil. The reason a hydro-foil would be considered hydrodynamic is that the foil can operate only while the ship is moving.

Magnetic Suspension

Magnetic suspension involves the use of magnetic fields, which create "magnetic cushions" between the vehicle and the surface on which the vehicle is traveling. According to Bender (1983), "[t]he magnetic suspension system is used in con-

junction with iron rails on a guideway, and like the air cushion, eliminates continuous physical contact between the vehicle and the guideway or medium" (p. 38). This type of suspension system can be found in land vehicles operating with linear induction motors (LIM) as discussed in an earlier section concerning propulsion. Magnetic suspension can also be provided in land vehicles through the use of superconducting magnets in the vehicle which create powerful opposing forces that repel (push) a vehicle up from an opposite magnetically charged guideway.

Guidance

Guidance is simply a means to provide information to a vehicle operator. The operator of the vehicle (either human or machine) needs information to control the direction, velocity, and/or altitude (for air and space vehicles) of the vehicle. Vehicle control will be discussed in the next section. Information can be provided to a vehicle operator by either visual or electronic means.

Visual Guidance

Visual guidance provides information that can be seen with human eyes or machine vision sensors. Visual guidance may be provided to land vehicle operators from information and directional signs, various types of stripes painted on roadways, traffic lights, and road maps. Visual guidance for marine craft operators may come from charts, buoys, a lighthouse, stars, land formations, or a compass heading. Air vehicle operators may obtain visual guidance from visual flight rules (VFR—landmarks, bodies of water, etc.), maps and charts, and through observation of radar and various types of onboard indicators (such as speed, altimeter, directional gyroscopes, turn and bank, and others).

Electronic Guidance

Electronic guidance provides information that can be transmitted and received by telecommunication devices such as radios, satellites, and telephones. This information can be interpreted and used by human or machine vehicle controllers. Computers located in the vehicle are often used to assist in the interpretation of location and directional data that is received from these telecommunication devices.

One example of an electronic guidance system often used in air and marine vehicles to triangulate their location is an omni-VOR device. Another example of electronic guidance is provided by the inertial guidance gyroscope found in missiles and space vehicles. Research is also currently being conducted to develop practical applications of many electronic guidance principles to land-based transportation vehicles.

Control

While guidance provides information, control is action taken to bring about the movement of a vehicle. The action is taken by a vehicle operator. Action taken by a human operator is called manual control and action taken by some mechanical or electrical device (including computers) is referred to as automated or remote vehicle control. Semi-automated control occurs when "there are both manual and automatic or remote control elements" (Bender, 1983, p. 41).

Vehicular movement can be brought about by a change in velocity, direction, or altitude/depth. These three types of movement are referred to as degrees of freedom. Generally, vehicles that are designed with greater movement capabilities require more complex guidance and control systems.

One Degree of Freedom

Transportation vehicles that allow for control in only acceleration and deceleration (velocity) movement are said to have one degree of freedom. These types of vehicles are guided along fixed pathways with little flexibility in their routing. Examples of vehicles that possess one degree of freedom include railroad vehicles, elevators, tube vehicles, pipelines, conveyors, and moving sidewalks.

Two Degrees of Freedom

Vehicles that can be controlled with two types of movements (velocity and direction) possess two degrees of freedom. The addition of a variable direction movement adds much greater flexibility to vehicles such as automobiles, ships, bicycles, forklifts, industrial robots, snowmobiles, and hovercraft.

Three Degrees of Freedom

Vehicles with three degrees of freedom require velocity control, directional control, and altitude/depth control. Included are propulsion driven balloons, airplanes, missiles, helicopters, submarines, and spacecraft. "Guidance [and control] systems

for vehicles with three degrees of freedom are the most complex and are usually semi- or fully automatic" (Bender, 1983, p. 39).

Acutators

Movements in vehicles are controlled by devices called actuators. According to Bender (1983, p. 42), actuators provide power to change or maintain the speed, direction, or altitude of a vehicle. He states that:

> Actuators may be grouped into several categories: (1) mechanical, (2) pneumatic, (3) hydraulic, and (4) electric. A lever is the simplest form of mechanical actuator. A spring- return diaphragm is an example of a pneumatic actuator. Oil operated cylinders are hydraulic actuators. Motor operated and solenoid actuators fall into the electrical category. These actuators are commonly used in combinations such as electrohydraulics and electropneumatic units used for actuation of vehicle control devices such as steering, rudder, and elevators.

The accelerator pedal and linkage to the carburetor are examples of mechanical actuators in an automobile to control acceleration velocity and the brake pedal, brake lines, and brake shoes or drums are examples of mechanical and hydraulic actuators used to control deceleration velocity. Directional control in an automobile is brought about through mechanical steering wheel, steering column, and rack and pinion gear actuators.

Combinations of hydraulic and mechanical actuators are used to control directional and altitude movement in airplanes. Ailerons control roll (banking) directional movement, the rudder controls right and left movement (called yaw), and elevators are used to control up and down (pitch) movement (Karwatka and Kozak, 1987). Further, electrical, mechanical, pneumatic, and hydraulic actuators can be used separately or in combinations to control movement in industrial robots.

Structure

Structure provides a basic shape to a transportation vehicle and can be used to enclose passengers in safety and comfort. "Basic vehicular structures generally consist of a frame and enclosure or body . . ." (Bender, 1983, p. 45). Structure also provides a base to fasten vehicle components such as the power plant, other related propulsion elements, control devices, suspension parts, and guidance systems. Each type of transportation vehicle has its own unique structural requirements based on the environment (land, air, water, or space) through which it travels.

The basic structural elements in land and air vehicles are the frame and body. Many modern automobiles have a combination frame and body structure called a unibody. Most airplanes are constructed with a monocoque structure. This type of structure consists of multiple subframes made up of ribs and stringers tied together by a sheet metal body or skin. Bender (1983) indicates that the monocoque structure is ". . . now universal for wings, pods, fuselages, and tail surfaces" (p. 47). Some land vehicles including racing automobiles are also produced with a monocoque structure.

Structure in many marine and space vehicles is provided basically by the hull, bulkheads, and deck(s). Bulkheads provide vertical structure and the deck or decks provide horizontal structure to the vehicle. The hull is the major structural element to which all other elements (masts, engines, bridge, manipulator arms, cargo-bay doors, heat resistant ceramic tile, etc.) are attached.

Support

Support in transportation generally refers to methods used which enable transportation vehicles, pathways, and flow patterns to operate safely and efficiently. Bolyard (1986), identified five support systems that can be applied to the land, marine, air and space environments of the transportation system. These are life support, operations support, legal support, economic support, and maintenance support.

Life Support

Life support includes all methods and devices used to maintain the physical and mental well-being of passengers traveling within the vehicle. Examples of physical life support devices may include seat belts and shoulder harnesses, air bags, padded dashboards, safety glass windshields, collapsible steering columns, seat headrests, head protecting helmets, life vests, oxygen tanks and breathing apparatuses, ejection seats or escape capsules, parachutes, space suits, fire retarding upholstery, fire extinguishing equipment, and more. Examples of mental life support systems may include radios and tape players, interactive computer simulations, books and magazines, and games.

Operations Support

Operations support refers to structures that support the weight, provide locations to load/unload passengers or freight, provide points for departure/ arrival, or control the flow pattern of vehicles. Land transportation operations support may include traffic lights, bridges, roadways, tunnels, bus terminals, and train stations. Marine transportation operations support may include harbors, docks, piers, waterway flood control and locks, towboats, and ice booms.

Air transportation operations support includes airport control towers and air traffic controllers, runways, shuttle buses, baggage handling facilities, ticketing and reservations systems, marking systems, parking lots, and helicopter landing pads. Finally, space transportation operations support includes launch control centers, testing facilities, launch pads and platforms, vehicle assembly buildings, astronaut training facilities, and flight tracking equipment.

Legal Support

Legal support refers to all laws, regulations, and regulatory agencies that control traffic flow and vehicle operation within each of the four environments of the transportation system. A curricular organization of legal support should include concepts dealing with insurance, right-of-way, licensing, titles of ownership, inspections and pollution control.

Also included can be a study of the operation of regulatory and assistance agencies such as the Federal Aviation Administration (FAA), Coast Guard, Harbor Patrol, local and state police, the Environmental Protection Agency (EPA), Department of Transportation (DOT), the International Commerce Commission (ICC), the American Automobile Association (AAA), and others.

Economic Suppport

Economic support refers to ways that the local, state, and federal government generates money to maintain and expand existing transportation facilities or build new facilities. Included are gas taxes, roadway usage taxes, tolls and fares, bank financing, bond issuing, federal funding, and others.

Maintenance Support

Finally, maintenance support involves all facilities where maintenance and repair operations are performed on transportation vehicles. Garages, service stations, dealerships, dry-docking facilities, aircraft and spacecraft hangers, along with the service personnel represent maintenance support in the transportation system.

Technology Education System Outputs

The outputs of technology education systems represent goals or ends that system inputs and processes are designed to produce. A study of system outputs should be included in any curriculum that is attempting to provide students with a holistic perspective of technology education.

The four technology education systems described in this monograph have a certain number of common system outputs. These include new knowledge, new or more efficient processes, impacts (social/cultural, environmental, etc.), and services. New knowledge is essential to solve existing problems and expand human potential. New and more efficient processes lead to greater productivity and less waste within each system. System impacts, good as well as bad, need to be continuously examined and debated so that our citizens can make better informed decisions as a voting electorate.

Additional outputs, uniquely related to each system, are also provided. The communication system provides communicated information. The construction system provides new or remodeled structures, the manufacturing system provides new materials and manufactured products, and the transportation system provides people and resource mobility. Any of the system outputs identified above can serve as a focal point for designing one or more units of study relating to technology system outputs.

Summary

This monograph provided a synthesis of literature that described suggested content and activity areas of technology education. The content organizers were based on the Jackson's Mill Curriculum Theory (Hales and Snyder, 1981), a wide variety of recently published technology education textbooks, technology education state curriculum guides, historical curriculum models and subject matter contributing to the evolution of technology education, and the actual classroom experiences of this author and his colleagues at Fairmont State College.

The discussion initially focused on the evolution of technology education and a description of a universal systems model. The systems model was used to provide the structural framework for codifying the body of knowledge called technology education. The universal systems model was then applied to introduce four systems of technology that are used by humans to adapt to their environment.

A detailed analysis of technology education systems followed. Included in this analysis was a discussion of six inputs considered generic to all four technology education systems. Separate descriptions of communication, construction, manufacturing, and transportation system process areas followed. A final discussion of technology system outputs was addressed at the end of the monograph.

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